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Inland Lake Watershed Analysis. A Planning and Management Approach

Michigan Univ -Flint Dept of Physical Geography

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INLAND LAKE WATERSHED ANALYSIS

A Planning and Management Approach

Michigan Department of Natural Resources
Land Resource Program Division
Inland Lake Management Unit

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The quality of water in an inland lake is closely related to environmental conditions in the watershed. As development takes place, these conditions usually deteriorate causing a decline in lake water quality. Planning and management of the watershed are essential to maintenance of lake water quality, but this requires a reliable information base and a methodology for watershed analysis. Lake area citizens can make important contributions toward the development of an information system on the watershed and shoreline. An analysis methodology can be formulated if the watershed is subdivided into two types of drainage areas: sub-basin and shoreland. The relative influence of sub-basins on the lake can be computed on the basis of land use, surface cover, and drainage features, and the capacity of shorelands to accommodate development can be defined on the basis of topography and drainage of frontage property. Planning and management guidelines should be designed to minimize the influence on the lake of the land use in sub-basins and shorelands.

INLAND LAKE WATERSHED ANALYSIS

A Planning and Management Approach

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III

FOREWORD

This monograph is concerned with the relationship between inland lakes and their watersheds and how lake watersheds can be analyzed for purposes of lake planning and management. The volume is organized into four main sections. The first describes the nature of the lake-watershed relationship; the second concerns the development of information on the lake environment; the third proposes a method for lake watershed analysis; and the fourth deals with the application of this method to the planning and management of the lake watershed.

The monograph was prepared under a contract from the Michigan Department of Natural Resources. Albert Massey and Dennis P. Tierney of the Inland Lakes Management Unit initiated and managed the project, and with the help of their colleague, Howard Wandell, provided valuable and patient guidance at each stage of its development. In addition to these gentlemen, several of our associates deserve thanks for contributing materials and ideas. They include Howard Deardorff, Peter Meier and Peter Van Dusen of the University of Michigan; John Grossa and Roy Klopcic of Central Michigan University; and Nancy Stieber of Applied Environmental Research. Jon Bamberger and Charles Schlinger contributed several photographs.

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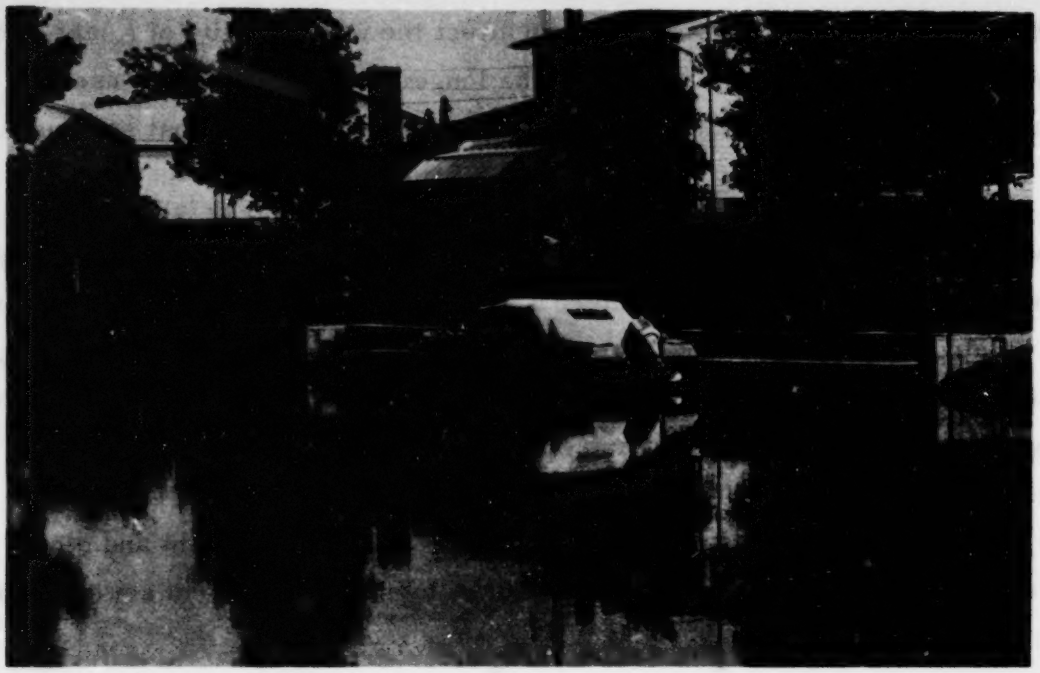


Inland lakes are one of Michigan's most valuable resources. As habitats for plants and wildlife, natural reservoirs of fresh water, and sources of stream flow, lakes are also one of the State's most fragile environments. With the development of improved highway networks, lakes which were formerly protected by distance are now within the urbanite's ready access. As a result, many lakes have undergone marked deterioration in response to intensive use of their water and surrounding land. Consequently, the amenities which have drawn us to the lakes, for example, the open space, clear water, fish, waterfowl, vegetation and the beaches are severely and often irreparably altered by our own activities.

Two types of human pressure can be identified in lake environments, namely, water use and watershed use. The first includes mainly short-term activities such as boating, swimming and fishing, which focus largely on the lake itself. The second includes longer term activities, such as

land development, which are centered in the area surrounding the lake. Although, the water use activities do affect the water quality of a lake, and often in a very obtrusive way, it is the longer term development uses of the surrounding land that usually affect lake water quality most seriously.

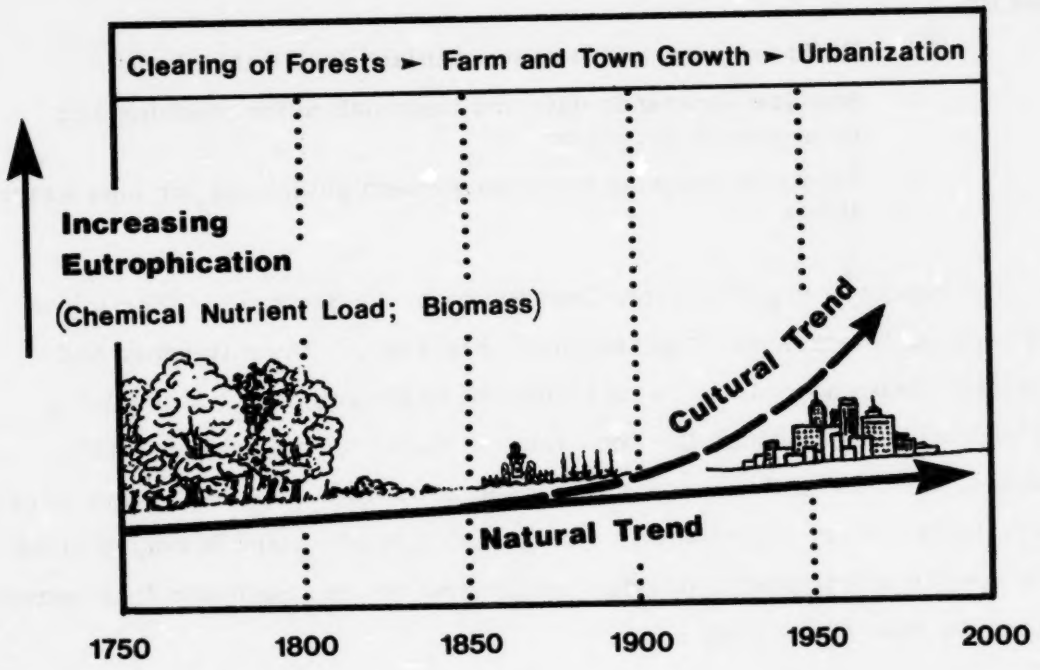
The reasons for this are fundamentally simple. The lake gains its water from an area of land around it called the watershed, and should the use of this land be radically altered, chances are that the quality of water it yields will be correspondingly altered. As the watershed is developed, forests are cleared and replaced with surfaces such as concrete and lawns which become depositories for the residue generated by humans, their machines and their animals. Ultimately, these surfaces are flushed by runoff, and the residues of fertilizers, oil, animal excrement and other foreign substances are carried to the lake by streams, storm sewers and drains.

With the addition of these substances to the lake water several types of aquatic changes may be triggered. The most common of these is a sequence of changes known as eutrophication. Despite the scientific mystique that may be evoked by this term, the meaning of the word is actually rather simple. Eutrophy refers to the increase over time in the quantity of chemical nutrients and living matter in the lake water. This change is referred to as aging. Simply put, as the mass of chemical and biological matter increases, the lake is said to grow older. By most standards, this usually represents a deterioration of water quality.

Lake aging is a natural process. However, not all lakes age at the same rate. The rate of aging is influenced mainly by the biological and physical conditions of the watershed from which and through which the lake gains its water. Changes in the watershed can alter the quality of runoff which, in turn, can influence the rate eutrophication. The rate can be increased or decreased in response to changes in vegetation, soils or surface cover, and the cause of these changes may be natural or man-made.

To most of us eutrophication is manifested in surface algae, abundant aquatic plants, changes in fish species and increases in the numbers and types of bottom creatures. But these features can also be observed in lakes that are untouched by man. Can lakes naturally undergo eutrophication? Yes, in fact, most do. However, the critical factor is the rate of eutrophication under natural conditions compared to the rate under human use conditions. Development of the shore and watershed almost inevitably fosters a faster rate of eutrophication than would be expected under natural conditions. And while it is perhaps impossible to avoid some increase in eutrophication due to development, the central issue in inland lakes planning and management programs is how to avoid the enormous increases which have already damaged scores of lakes throughout Michigan.

The relationship of land development to eutrophication can be made somewhat clearer with the aid of a diagram. The graph below illustrates the difference between man-induced eutrophication, or cultural eutrophication, and natural eutrophication. Notice that the natural trend represents a much slower rate than the cultural trend which increases rapidly in



response to the intensity and type of development. Although the natural conditions and the rates of land development vary from lake to lake, the watershed changes and the resultant trend in water quality changes portrayed in this graph appear to be fairly consistent throughout Michigan.

Over the past several decades, many scientific studies have been conducted on Michigan's inland lakes. Most of these studies have focused on lake water quality, especially water chemistry and its relationship to aquatic plants and animals. Although scientists agree that most water quality problems originate in the watershed, comparitively little attention has been devoted to the analysis of lake watersheds and how they can be planned and managed to maintain quality lakes.

This study is an attempt to further our understanding of inland lake watersheds so that we are able to make wise decisions regarding the use of the land that feeds the lake with water. Further, it attempts to identify clearly the watershed features and conditions that must be the focus of planning and management action in order to maintain lake quality. The objectives of the study are to design a set of non-technical methods that can be used to:

1. Build an information base on inland lake watersheds
2. Analyze watershed data and information for planning and management purposes
3. Establish planning and management guidelines for lake watersheds.

The report is organized into four sections. In Section I, "The Inland Lake and Its Watershed: A Development Scenario," the watershed and shoreline changes known to be instrumental in shaping lake water quality are highlighted. Although the discussion is based upon actual scientific findings, the description centers on a hypothetical lake and watershed whose characteristics are representative of typical medium-sized Michigan lakes. This section is intended to provide background on the origin and development of today's inland lake problems.

Section II, "Building An Information Base for Inland Lake Planning and Management," identifies a set of watershed and shoreline characteristics which can be monitored and systematically recorded by the resident, land owner or local official. The information is designed to provide a suitable starting point for watershed analysis, planning and management activities that can be undertaken in conjunction with the DNR, regional, county or local planning and environmental agencies. This section is summarized by a list of questions intended to serve as guidelines for building the information record on a yearly basis.

Section III, "Analysis of Inland Lake Watersheds: A Methodology," describes an approach to the analysis of lake watersheds and features examples from several lakes and watersheds which have been altered by various kinds of development. The examples range from Reeds Lake in urban East Grand Rapids to Townline Lake in rural Montcalm County. For each watershed, two types of drainage sub-areas are defined. These are called shorelands and sub-basins. The influence of sub-basin drainage on the lake is defined on the basis of the changes in the quality and quantity of runoff resulting from different types of development. For each sub-basin this is computed from land cover, land use and drainage data and is expressed by a number called the influence factor. This method provides a means of identifying critical areas in the watershed and ranking sub-basins for planning and management attention.

Section IV, "Planning and Management Guidelines for Inland Lake Watersheds," is the final section of the study. Here a set of guidelines is defined for shorelands and sub-basins. The guidelines are based directly on the analytical methods described in Section III. Shorelands are classed into three orders, each of which carries a specified development capacity. Six guidelines are defined for sub-basins and these are designed to minimize the influence of sub-basin drainage on lake water quality.

section 1

Formation of inland lake basins and watersheds

Lake changes due to natural sedimentation and organic filling

Early influences of modern man

20th century pressures on the lake environment

INLAND LAKE FORMATION :

A Development Scenario

To help establish a perspective on the problems of lake planning and management, it is necessary to outline the important natural and human events in the formation and development of a typical inland lake. Such a discussion could be exceedingly long and cumbersome; so in order to streamline it somewhat we have decided to present it in outline form. Let us call it a scenario.

A scenario is defined as... "the outline of a play... showing its development scene by scene..." Though the word comes to us from the theatre, it is particularly appropriate for a description of inland lake development for several reasons. First, by standards of human time, most lakes are very old, usually around 10,000 years, and in order to comprehend their formation and development, we must compress the natural time scale

to a mere outline. Second, lakes tend to develop sequentially as if by life stages which have the aspect of scenes. Third, in the last 100 years or so human use of inland lakes has provided an element of drama which shows every sign of determining how and when the "inland lake play" will end.

Glacial Ice

After Thaw

formation of the watershed

As little as 12,000 years ago, most of what is now Michigan lay under massive sheets of glacial ice. As the ice sheets wasted away they tended to break up into irregular blocks which were left scattered across various parts of the terrain. The waters which poured off the melting glaciers deposited sand and other sediments around the blocks, fully or partially burying them. In time, the climate warmed sufficiently for the blocks to melt, leaving pits or depressions in the land, which became the basins for most of Michigan's inland lakes.

As this was taking place, many other important geo-physical processes were developing in the landscape. Chief among these was the formation of drainage basins. Streams became integrated, drainage divides became established and essentially all the land was partitioned into water collection areas, or watersheds. Below the surface, ground water filled the empty spaces between the particles in glacial deposits. Owing to the great depth of many of the basins left by the ice blocks, ground water flowed into them, filling them to a level even with that of the water table. And so the inland lakes were formed; but how were they maintained over the centuries?

Actually, many lakes were not maintained and they went dry as the water table declined after glaciation. But for those which have lasted through the millenia, certain hydrologic conditions were necessary. First, a relatively high water table had to be maintained, which demanded a favorable balance be-

tween ground water inflow to the lake and ground water recharge from the surface of the watershed. This necessitated a watershed of sufficient size to collect enough surface water to recharge the ground water as well as supply water to the lake in the form of surface runoff. Second, the total water losses from the lake resulting from evaporation, soil seepage and stream outflow could not exceed inflow, else the lake would dwindle away.

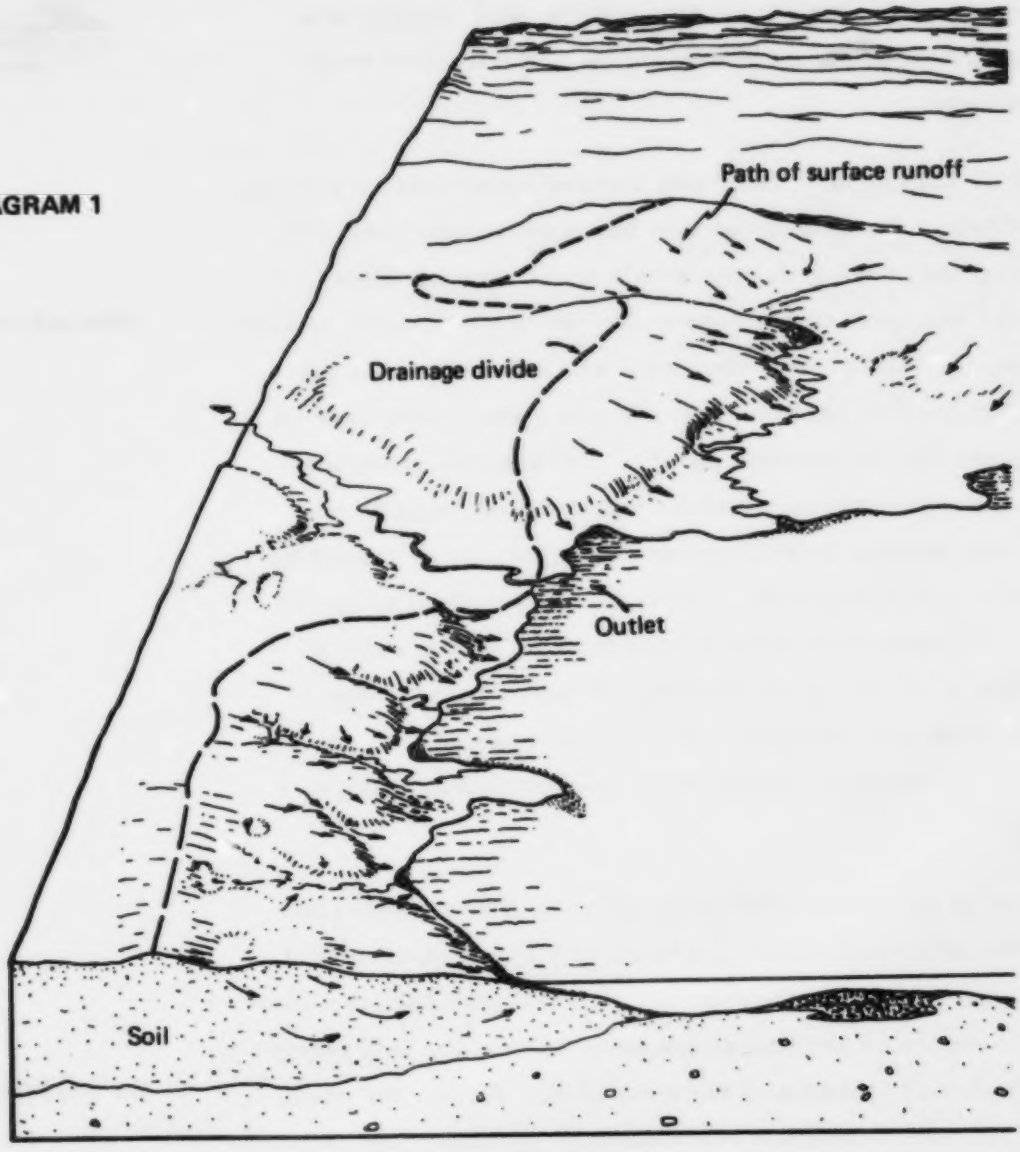
initial sedimentation

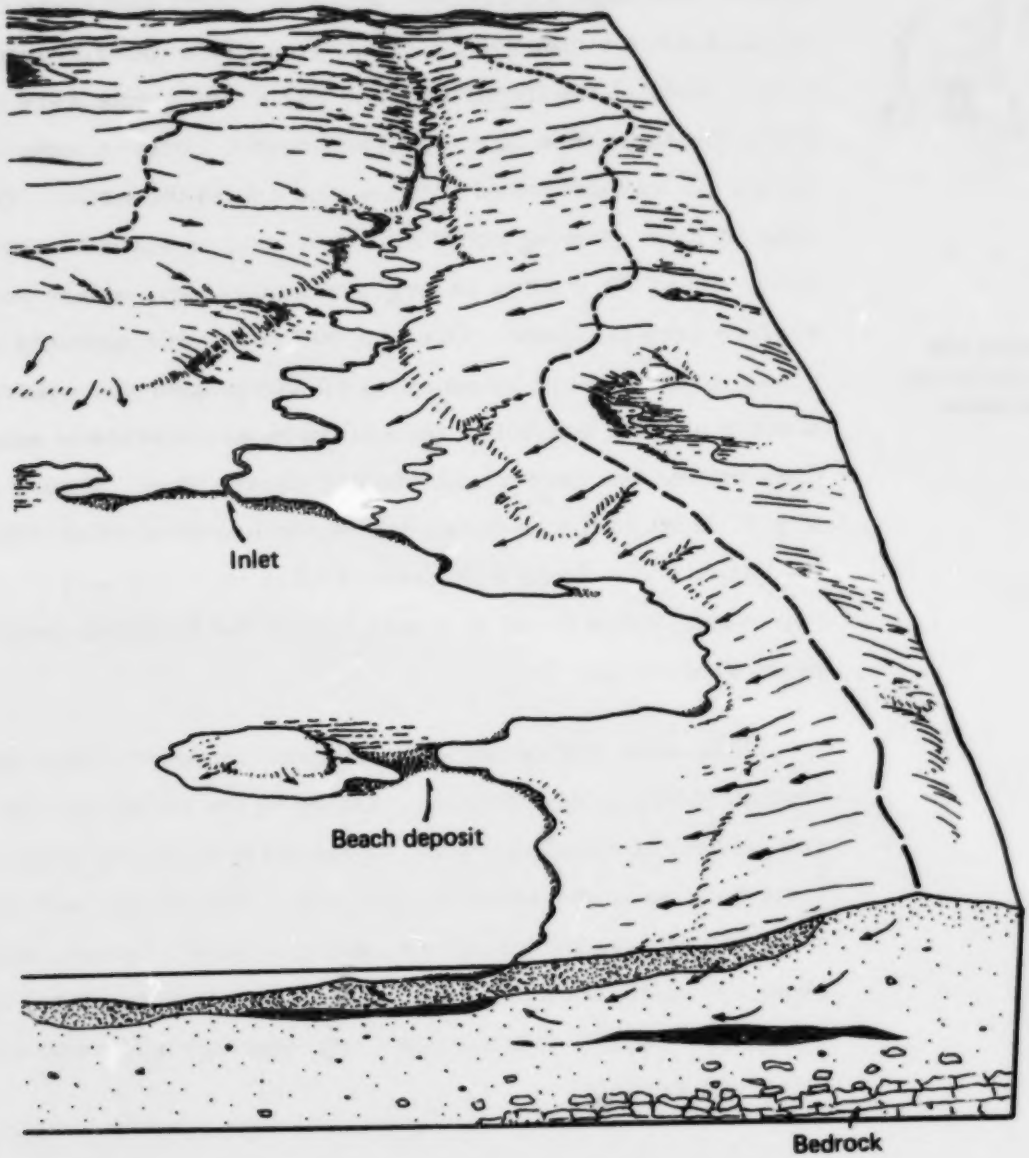
With both ground water and surface water flowing into the lake, physical changes in the lake basin were inevitable. By examining the present-day materials around inland lakes, we know, for example, that streams carried large amounts of sediment into the lake basin. Most of it was deposited near the shore, but the fine particles, mostly the clays, were carried by currents into the deepest parts of the lake and deposited there. As the centuries passed, the shoreline deposits built up near the mouths of the streams where they were eroded by waves and currents and the sediments redistributed along the shore. The sediments accumulated in bays, at the ends of points and in the lee of the islands. In this way the shape of the lake basin was changed, new land was created and, most importantly, the total volume of the lake basin was inevitably reduced.

the hypothetical lake

Let us attempt to show schematically these geophysical processes in the watershed and basin of a hypothetical inland lake. Diagram 1 is a rendition of a youthful lake and its watershed. In the land surrounding the lake, the broken line represents the drainage divide of the watershed. Within this perimeter, all runoff, whether in the form of overland flow, streams or ground water, flows toward the lake and about thirty percent of it actually reaches the lake. The arrows on the surface

DIAGRAM 1




Inlet
Beach deposit
Bedrock

depict the pattern of overland flow and those below the surface depict the pattern of ground water flow. The dot pattern shows the areas of sediment deposition in and around the lake basin.

production and decomposition of organic matter

While the geophysical processes were taking shape on the new land, plants and animals began to inhabit the lake watersheds. Although the geologic deposits reveal that some of the animals were strikingly different from those found around lakes today, most of the important land and water plants were essentially the same then as now. The organic matter produced by the plants was deposited both on land and in the water. Depending on local growing conditions, the rate of deposition ranged from 20 to 70 ounces of organic matter per square yard of surface area per year. Over 10,000 years this amounts to a gross plant output of as much as 40,000 pounds per square yard. But the organic content of the soil in most watersheds generally does not exceed several pounds per square yard. Where did it go? Most of it was consumed by the bacteria which reside in the upper soil. Some was carried away by runoff and wind. In any event, virtually all of it was lost in the forested areas of most watersheds.

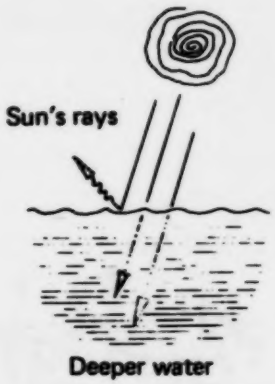
The lake and associated wetlands, however, were an exception to this generalization. Owing to the relatively low oxygen content of standing water, bacterial activity were not efficient here as in the aerated upper soil. Therefore, the consumption of organic matter was slow; so slow, in fact, that it generally could consume only a fraction of that deposited annually. As a result, thick organic deposits formed in and around lakes and wetlands.

The picture, of course, is more complex than we have outlined above and it is necessary that we explore it a bit further

before returning to the lake in Diagram 1. The rate of organic accumulation in lakes and wetlands was controlled not only by intensity of decomposition, but also by the rate of production of organic matter by aquatic and wetlands plants. Certain environments were far more conducive to high production rates than others because they provided better conditions for plant growth.

productivity of aquatic plants

In general, any aquatic setting which provides large and dependable supplies of light, heat and nutrients would foster high rates of plant production. Water depth is one of the most important controls on these forms of energy. More than half the light which enters a lake is absorbed and converted to heat in the upper three feet of water. Therefore, shallow water bodies can foster much denser plant covers and faster plant growth rates than can deep water bodies. Moreover, due to the smaller volume of water held in shallow lakes, nutrients added by rainfall, runoff and ground water tend to become more concentrated than in deep lakes. In other words, for two lakes with the same surface area, the deeper one has a greater volume of water through which to diffuse nutrients than does the shallow one. This fact is especially important when we realize that rainfall alone contributes 8 to 10 pounds of nitrate annually to every acre of lake surface. For a lake area of 100 acres, for example, the total nitrate input from rainfall amounts to 1,000 pounds per year.

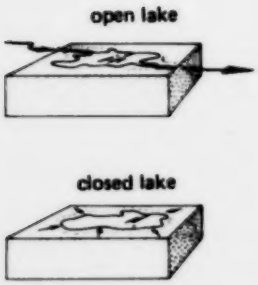


Another influence on aquatic plant production was the nature of vegetation and soils in the watershed. The material deposited by the glaciers tended to vary in its chemical composition from place to place. In some areas, limestone pebbles were abundant and they yielded calcium to the ground water. Carried into the lake, this mineral helped nurture vigorous aquatic plant growth.

nutrient input from watershed

The type of trees in the watershed forest cover was also an important influence on the nutrient content of the lake water. Trees draw large amounts of nutrients from the soil. As they complete their seasonal and life cycles, the nutrients are returned to the soil as the organic litter. Invariably, some of it is washed into the lake by runoff where it slowly decomposes and adds nutrients to the lake. Because nutrients such as phosphorus are found in greater concentration in broadleaf trees than in evergreen trees, watersheds which were forested in trees such as oak, maple, elm and ash tended to contribute more nutrients to lakes than did those forested in trees such as pine, spruce and balsam fir.

Certain high intensity natural events also influenced the nutrient content of the lake. For instance, forest fires appear to have been common in prehistoric times and the ashes they produced were readily washed into the lake along with leaves and soil sediments. The ashes, in turn, yielded phosphorus to the water.

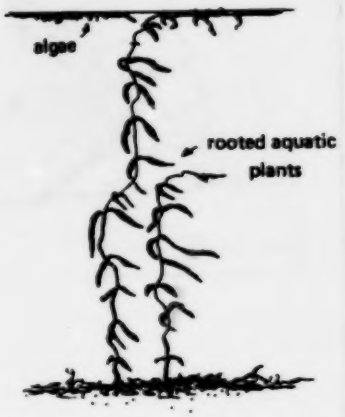


Finally, it is necessary to add that the total concentration of nutrients contributed to the lake from these sources was regulated also by the flushing capacity of the lake. Flushing capacity is a measure of how fast total volume of lake water can be replaced with new water. Lakes which form a link in river systems may be flushed several times a year. Much of the nutrient content of such "open" lakes is regulated by the quality of inflowing river water. If the river is low in nutrients, then the lake water will also be low and plant growth will be held down. The opposite, of course, can also be true. It should be added that flushing by rivers can remove floating and submerged organic material as well as nutrients.

In contrast to the open lake are lakes without river outlets, or "closed" lakes. These lakes release their water mainly through evaporation and seepage. Replacement of lake water is normally very slow and the nutrient concentration may increase with the years, nurturing heavy growths of aquatic plants. Many of Michigan's bogs are the products of closed lakes within which organic matter accumulated so fast that the lake was completely filled in the course of several thousand years.

signs of eutrophication

Returning to our hypothetical lake, we find that aquatic plants have become abundant in the shallow waters of the basin. Reeds and cattails are prevalent along shores protected from strong waves. Off shore, large submerged plants grow toward the surface from depths as great as fifteen feet. And in the surface layers of the lake, dense patches of algae flourish with the onset of each summer.



In the deep parts of the basin, rooted aquatic plants are absent. However, algae still grow in the surface layer and often much of it is carried into offshore shallow water by the waves and currents of summer and fall. As a result, the deep parts of the basin collect only small amounts of organic debris over long periods of time. But the picture is somewhat different for the shallow bays where both the rooted aquatic plant density and algal growth rates are very high. Sheltered from the strong waves and currents of the main body, bays are depositories for floating and submerged materials. As a result, the bays retain most of what they produce as well as that which is carried into them, and subsequently fill with organic debris. Add to this the sediments deposited by streams, and it is easy to envision how bays are transformed into wetlands.

Diagram 2 attempts to show the pattern of plant growth

DIAGRAM 2

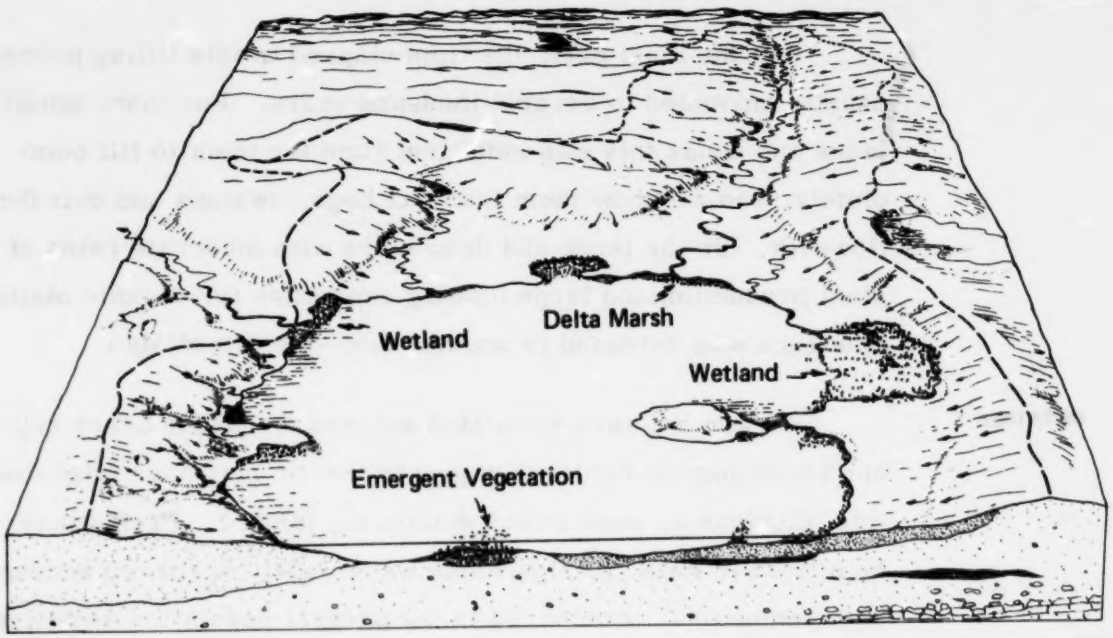


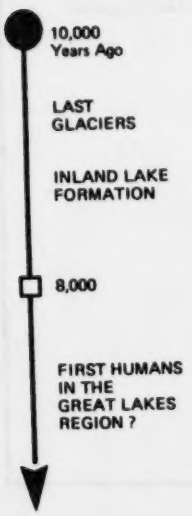
DIAGRAM 3

in the lake. The inset in the diagram portrays a partially filled embayment--a typical scene around many lakes today. Diagram 3 carries the sequel somewhat further and all the embayments around the lake have been transformed into wetlands, reducing the area of the lake by about fifty acres. Thus, the processes of eutrophication are present and active before the lake has felt its first man.

For the most part, the time elapsed in this filling process usually amounted to several thousand years. For many small lakes and ponds this was sufficient time for them to fill completely, and we know them today as bogs, swamps and marshes. However, for the large and deep lakes with moderate rates of plant production and large holding capacities for organic matter, existence was extended to another era--the era of Man.

early man

We are not sure when Man entered the Great Lakes region, but archeological evidence suggests that he may have migrated into Michigan as soon as the glacial ice melted. Prehistoric Man lived in small groups which were widely scattered across both peninsulas. Compared to the present population densities in the State, the Indian was hardly noticeable in the land and his influence on lakes and streams was so slight that we cannot discern it even with the aid of modern scientific techniques.



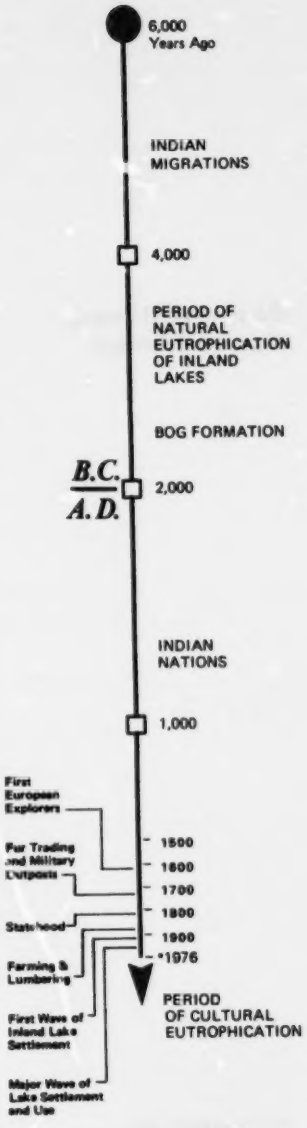
Early interest in Michigan's inland lakes centered mainly on game, fur, fish and travel. In the seventeen hundreds and the first half of the eighteen hundreds, most inland lakes were only occasionally visited by Indians and Whites alike. However, with the rise to Statehood, population grew, agricultural lands were expanded, and farms and villages began to appear on the shores of certain inland lakes. By 1850, the watersheds of many lakes in the southern part of the State had been partially

cleared for farms. After 1850 ambitious lumbering operations spread northward into most of the major lake regions of the State.

Land clearing by farmers and lumbermen was probably the first major impact by humans on Michigan's inland lakes. Studies of modern clearing operations indicate that deforestation results in an increase in soil erosion and runoff from the watershed and it is safe to surmise that early clearing operations produced similar results. What were the effects on the inland lake? Increased sedimentation and additional nutrients such as phosphorus from dead and burned vegetation were among the most important.

These effects, however, were shortlived in most instances, for in the absence of continuous use, the watershed in time became reforested. Where watersheds were converted to farm land, though, high runoff and sedimentation continued for decades. Based on historical records it appears that some lakes in the agricultural areas of the State have been under the continuous influence of intensive land use for 150 years or more. However, for Michigan inland lakes as a whole, pressure from agriculture alone must be considered slight compared to that brought on by the development of this century.

With the automobile, the improved roads and the rapid growth of State population came the next wave of human impact on inland lakes. Until World War II this was mainly recreational, but it did entail the development of cottages, roads and other related facilities. Some of the finest lakes in the southern part of the State became extremely popular and were intensively developed as early as 1920. Unfortunately, much of the development was makeshift



and clearly in violation of what we now consider to be essential principles of lake management. Foremost among the violations was the release of domestic sewage directly or indirectly into the lake. This practice all but ruined a number of lakes owing to 1) the massive growths of algae and other weeds that it nurtured and 2) the unsanitary water conditions that it produced, which in many cases restricted the lake from bodily contact altogether. In terms of the general life history of Michigan's inland lakes, this initial wave of residential development induced a new high in the rate of eutrophication.

the post-WWII wave of lake settlement

The second, and strongest, wave of lake development began after World War II and is still in progress. It is characterized not only by cottage development tied to recreation, but also year-round residential development and the growth of lake communties. Several trends and events of the 1950s and 1960s promoted this powerful wave of development: First, the domestic sewage problem was brought under control, thus insuring better protection of lake water quality. Second, the interstate highway system greatly reduced travel time between urban centers and lake areas, thereby facilitating not only recreational use, but also residential development. Third, the increased strength of Michigan's economy afforded more and more people the privilege of lake property ownership. For those lakes within reach of the urbanite, development advanced at unparalleled rates in the 1960s and 1970s and lake property values soared correspondingly.

the pressure for more building sites

As the limited supply of premium development sites were consumed, prospective property owners and developers were faced with one of two alternatives: 1) push on to lakes further north or 2) use "second rate" sites on the more accessible lakes. These are sites, such as wetlands, which pose serious

limitations to development. Of course, both alternatives have become popular, but let us examine the second one, for it shows signs of being especially important in the developmental history of inland lakes.

Poor drainage and organic soils tend to be the chief limitations to development in lake areas. Around the lake shore, both of these conditions are found in wetlands. If a wetland is large, channels are usually excavated across it in an effort to link the lake to better sites on the wetland fringe. On the other hand, if a wetland is relatively small, it is usually filled, or excavated first and then filled. In both cases, the results are detrimental to the lake: 1) contact between land use and lake is increased and 2) the important hydrologic functions of the wetland, such as regulating the inflow of runoff, are damaged. As a result, poor quality runoff from developed land is given relatively free access to the lake.

filling and dredging

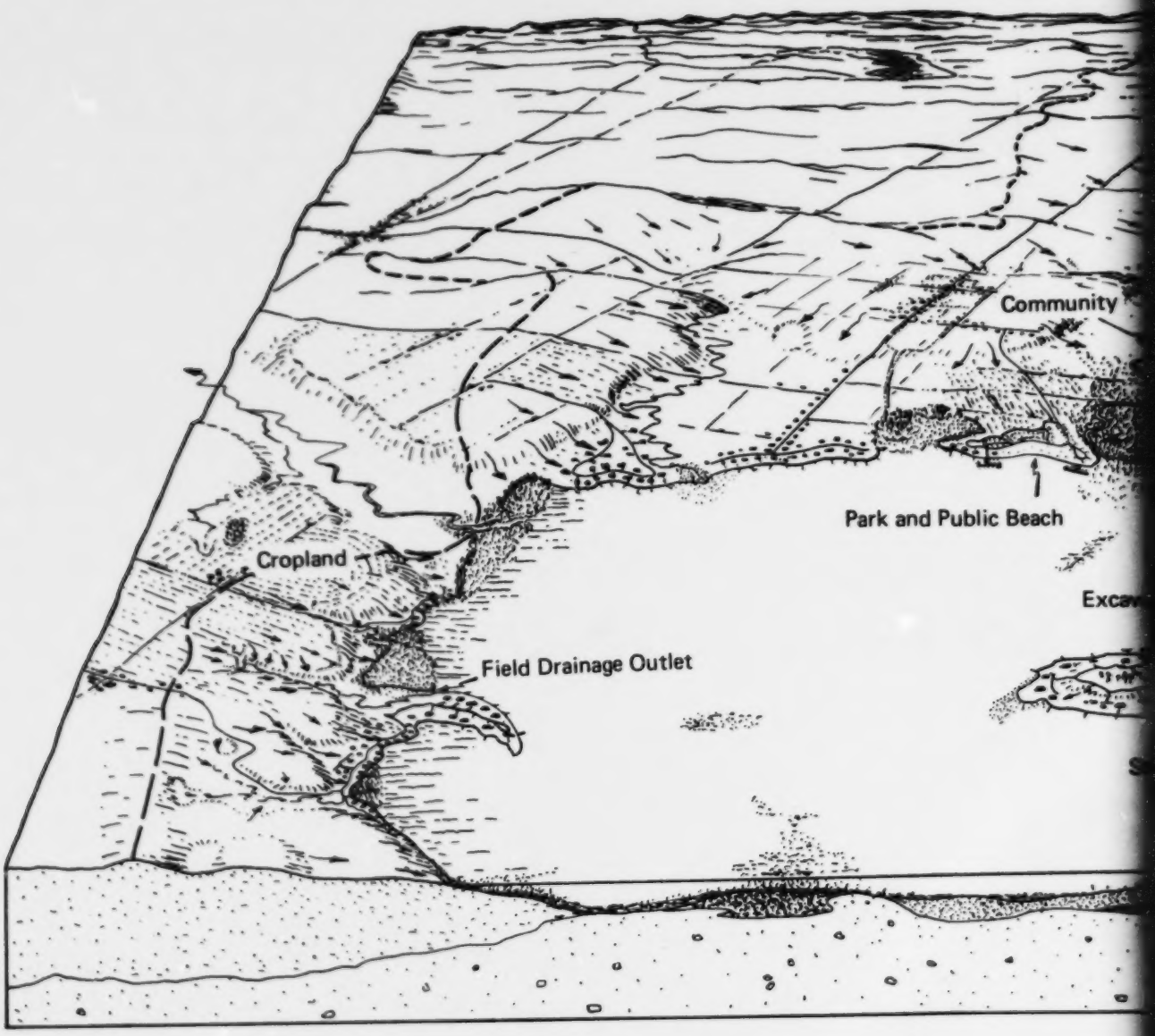
The modern development which has strongly affected Michigan's inland lakes is not only limited to shorelands. Indeed, the growth of lake communities has resulted in extensive development of the upland area of lake watersheds as well. Although separated from the lake by distance, community development in the watershed may have a profound influence on lake water quality. This is generally related to the establishment of storm sewer systems which link the community to the lake. During periods of runoff streets, yards, parking lots and so on are flushed of physical, chemical and biological residues, much of which is ultimately deposited in the lake by the storm sewer discharge. Not only do these materials contribute to a direct, short-term decline in water quality, but the chemical nutrients among them are now understood to contribute significantly to long term eutrophication.

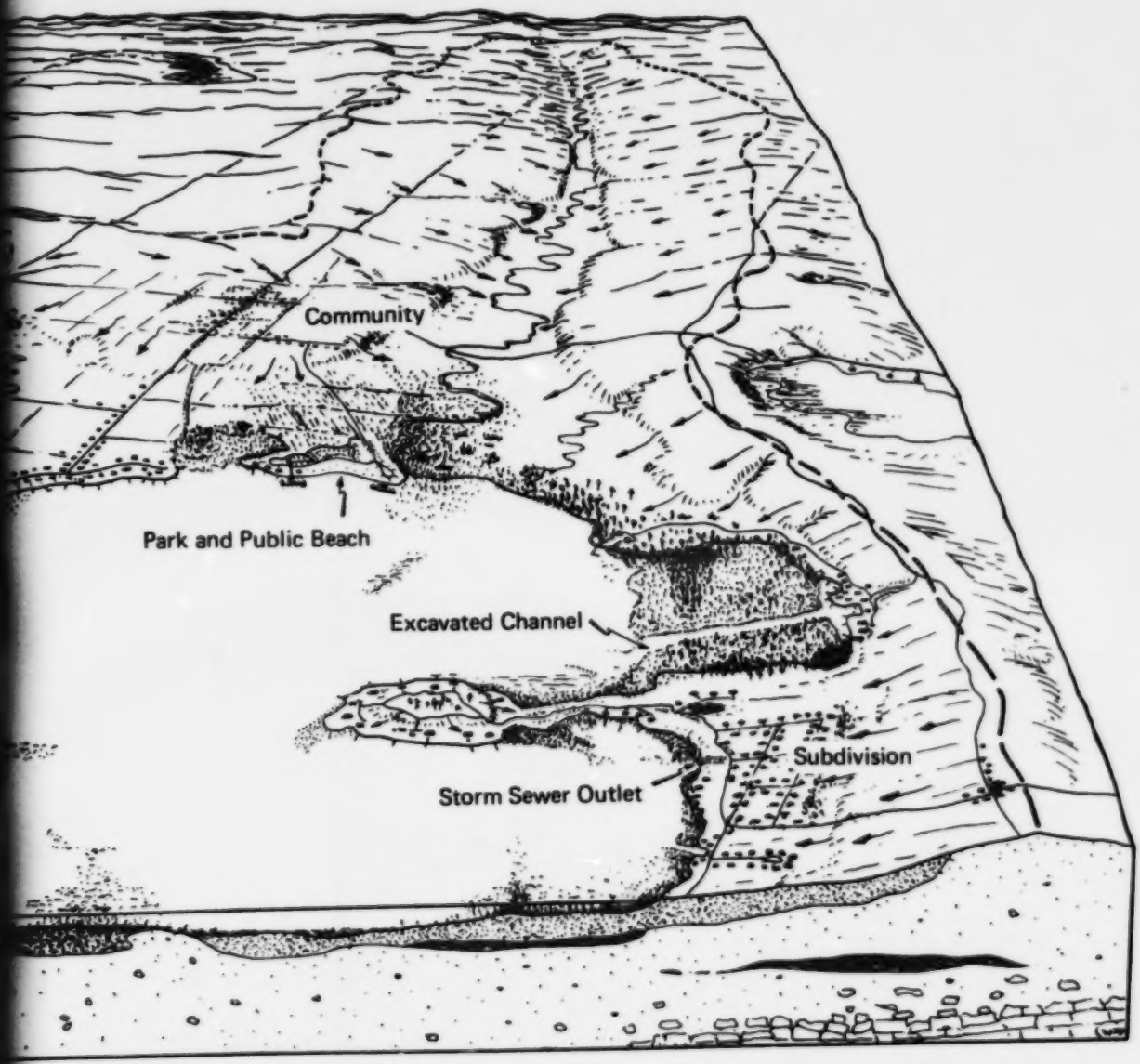
Let us return for the final time to our hypothetical inland lake. By World War II, many cottages have appeared along the more scenic segments of shoreline and the careful observer may have begun to note an increase in algae around the shore. In the watershed, farmers have cultivated several hundred acres of land for the past sixty or seventy years and each spring the ditches and tiles emanating from the fields have carried sediments to the streams which feed the lake.

By 1960, development has taken all the premium sites on the lake. Real estate values are rising, and by 1965 they are high enough to encourage a number of site improvement projects. The large wetland on the right side of the lake is breeched by channels, thereby opening the hilly land behind it to development. As development advances, signs of conflict between use of the shore and use of the lake are beginning to grow apparent. Multiple rows of "frontage" lots with limited shore access, new development in favored animal habitats, as well as numerous power boats, canoes and other floating apparatus are sure signs of active or impending conflict. In short, it appears that development has exceeded the natural capacity of the shoreline and the lake, as we attempt to show in Diagram 4.

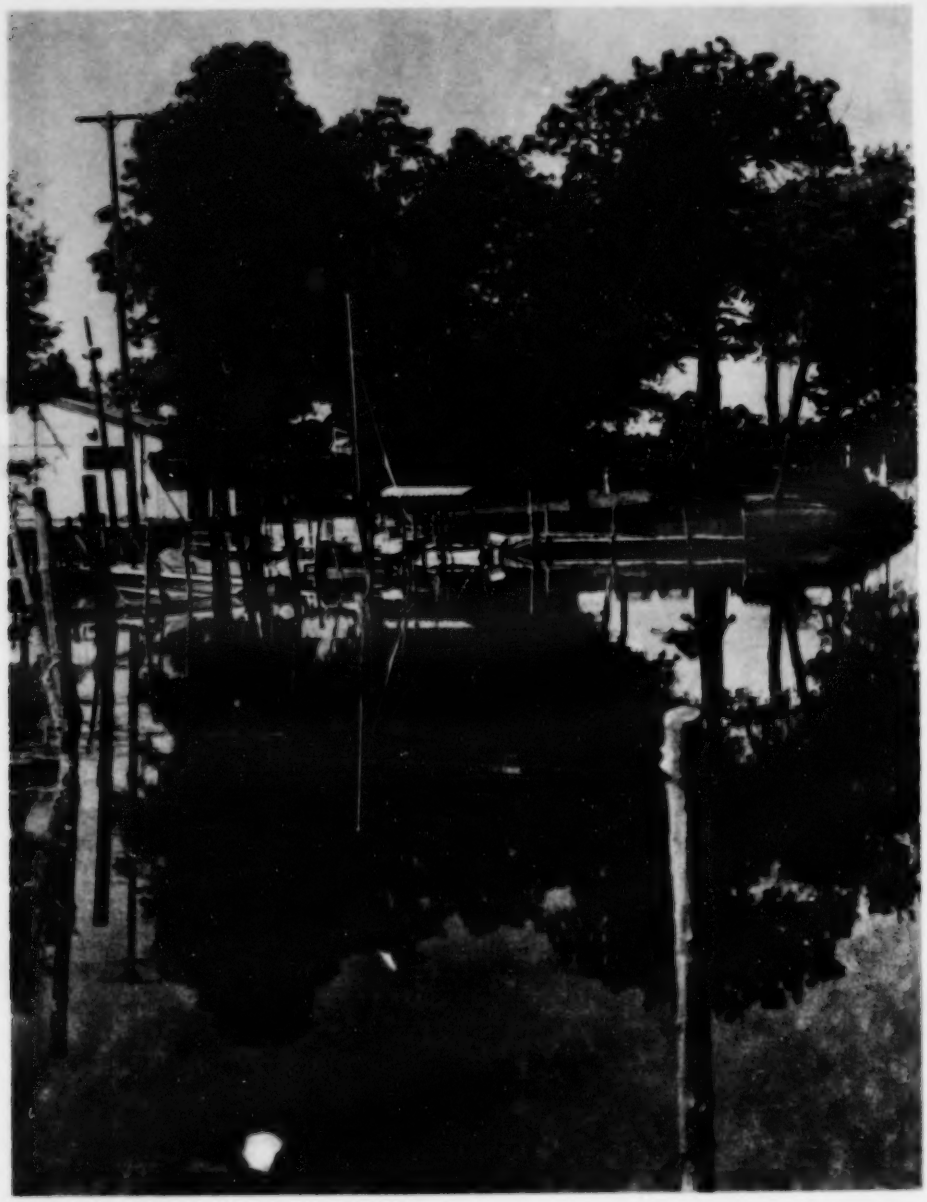
Ultimately, it is the lake, the very feature that attracted users in the first place, that is subjected to long term damage. Septic tank seepage, storm sewer runoff, yard drainage as well as cropland runoff in the upper watershed all contribute large doses of chemicals and sediments to the lake. Coupled with the natural inflow of these materials, the lake is now subjected to unparalleled rates of loading. These substances in turn promote many biological changes in the lake, chief of which is an accelerated rate of biological productivity. By most measures this spells a decline in the aesthetic and recreational value of

DIAGRAM 4


Community
Park and Public Beach
Cropland
Field Drainage Outlet


Community
Park and Public Beach
Excavated Channel
Subdivision
Storm Sewer Outlet

the lake. Since these changes have occurred over a period of only twenty to twenty-five years, lake residents begin to recall times when the lake was more pleasant and begin to ask what can be done to reduce or reverse the trend.



section 2

The need for accurate information on the lake environment

Citizens as observers and recorders of land and water change

The use of the grid system for recording information

Sources of assistance in initiating planning and management action

A SELF-HELP APPROACH TO LAKE WATERSHED INFORMATION

INTRODUCTION

The decisions that result in changes in lake water quality are those that call for alterations in the use of a lake and its watershed. These decisions take many different forms. Typically, they include decisions on new development, road construction, drainage engineering work, as well as changes in public and private use and management of the land and water. When a decision is made to place part of a watershed under a different use, the area involved is usually subjected to a series of physical alterations.

Change in surface cover is the most common alteration associated with the use of watersheds. Others include shoreline changes, alterations in the size and shape of the watershed

and alterations in the pattern and character of the drainage features. For example, if a forested area is converted to resort-recreation use, some of the vegetation will be removed and structures, roads and related facilities will be built. As a result, impervious surface material is introduced to the area and drainage patterns may be altered in the process. This, in turn, will likely bring about changes in the quality and quantity of runoff from the area. If the altered area is near the watershed drainage divide, local development may actually change the size and shape of the watershed itself.

land use decisions

Evaluating such development and its impact on the lake environment is an important problem. With pressure for changes such as these increasing year by year, it is critical that planning decisions be carefully weighed in light of their overall influence on water quality and the future of the lake. Moreover, it is essential in all planning and management efforts to develop an understanding about what is taking place in the watershed. In order to make informed judgements about potentially important cumulative changes in use and management, it is necessary to develop a means for assembling and evaluating the information. This requires formulating a perspective to help us observe, record and understand the processes of change in watersheds and inland lakes. The following discussion concerns the development of information on watershed conditions and how it relates to lake area planning and management considerations. This approach outlines a procedure for recording watershed data and information useful in evaluating the influence of existing and proposed land uses on lake water quality.

There are many natural and human processes operating in lake environments. The origins, interrelationships and effects

of these processes are complex and sometimes incomprehensible--at the scientific level anyway. But important data and information can be observed and recorded without scientific and technical knowledge and training. In fact, most of us are fully capable of making accurate observations on watershed processes and features and recording these observations in an orderly way.

information gatherers

Many lake areas are rich in people who are willing to collect, compile and use information on the lake environment. Through his everyday observations, the lake property owner can usually make important contributions to understanding both past and present changes in the lake area. These include shore erosion, wetland dredging, weed and algae growth, standing water, runoff and erosion from new construction, as well as special problems such as unauthorized discharge of waste material into the lake. These and many other changes can be noted by the resident who regularly observes the lake under a variety of conditions. If the observations are organized into an orderly record, they can serve as a reliable basis for evaluation of changing conditions.

the need for reliable information

Why is it necessary to organize observations into a systematic record? Invariably, decisions concerning land use planning and environmental management receive active opposition from certain individuals and groups. Experience shows that in the end it is often the original information that is challenged by the opposition. How credible is the information? Is it based on the memory of observations or on a record of observations that includes places, dates, conditions and so on? In the arena of a public hearing or a courtroom, there is little doubt that the systematic record carries far greater credibility than do recollections of casual observations. The greater the credibility, the better the chances that the information will serve

as the basis for decision-making.

the DNR self-help program

The Inland Lake Management Unit of the Michigan Department of Natural Resources has recently called upon lake citizens to establish a "self-help" program to monitor lake water quality. Under this program, citizens make observations and collect water samples which are then analyzed by the State for factors such as clarity and chlorophyl content. The resultant data provide an important basis for evaluating the "trophic" condition of lakes, thereby providing an indication of the developmental (aging) status of the lake.

As the preceding section of this report indicated, the condition of the watershed is the key to the condition of lake water. Accordingly, with the help of the procedures described in the following pages, it is possible to produce information on the watershed which can be correlated with water quality data from the self-help program. This information can help us answer the questions, "what will happen if this or that is changed in the watershed? and will the effects on the lake be undesirable?"

THE INFORMATION GATHERING METHOD

Recognition of the major processes and conditions in the lake and watershed is fundamental to building a record of observations and information on the lake environment. There are a variety of processes active in the water body, watershed and shoreline of every inland lake. These include waves, running water, ground water movement, nutrient exchanges, chemical transformation and biological activity. Processes are responsible for shaping the physical and biological features of the lake environment. For example, waves and running water

shape the shoreline, and climatic and biochemical processes shape the vegetation cover. Although processes are fascinating to observe, they are difficult to measure; therefore, we must often use the conditions of certain features of the environment as an indication of the status of processes. For instance, we can measure the biophysical features of a tree (e. g., leaves and trunk) and from them reach some conclusions about the status of photosynthesis, respiration and transpiration, the processes of tree growth.

processes of the lake environment

For our purposes it is essential to appreciate that as changes are made in the watershed through development or use, processes are thereby affected. This, in turn, changes not only the individual process, but the balance between interrelated processes as well. A prime example is the alteration of wetlands adjacent to a lake. Wetlands provide a natural retention and processing area for sediments, biological material and nutrients carried in runoff from upland terrain. If the wetland is dredged or filled, the effectiveness of this natural filter is reduced, and more sediments and nutrients may reach the lake, ultimately causing a faster rate of lake filling.

The design of an information system should ensure that the lake environment is monitored in a way that fosters understanding of the status, trends and interrelationships of processes as well as the ties between processes and features. Since there is so much to observe, decisions are needed as to which features of the lake environment should be observed and recorded. Four watershed features are especially important in matters concerning lake planning and management: land use, surface cover, drainage and shoreline.

monitoring change

land use

Land Use: Use of land is of primary importance in evaluating the causes of water quality changes. Land use is defined on the basis of the human activity that predominates in a particular area. Conventional types of land use include farming, recreation, industry, commercial and residential. Each type actually includes many different activities, but in general each represents a certain type of relationship between man and the environment. As the discussion concerning runoff in Section III indicates, each land use has a meas- different influence on water quality.

Land use information may be assembled from several sources. Direct interpretation of aerial photography is the most useful information source, especially if it is supplemented with field checks. In most areas of the State, aerial photographs are available from the local planning agency, the county road commission and the tax assessment or equalization offices. For agricultural areas, photography is also available from the Agriculture Stabilization and Conservation Service of the U. S. Department of Agriculture. Building permit and tax assessment records can also be valuable aids in maintaining a thorough record of land use changes. Where regional township, city, and county planning agencies are active, a completed land use inventory can usually be obtained upon request. While it may not provide sufficient detail for the land use record of lake watersheds, it will help in building the information base.

surface cover

Surface Cover: Changes in land use invariably produce alterations in surface cover. As we have stressed throughout this report, this is particularly apparent in the case of urban type development where extensive tracts of vegetation are replaced by impervious surface covers. This results in increased runoff from the surface which is often carried to a river or lake by storm sewers, ditches or improved natural channels. With each rainstorm the lake receives not only a large inflow of water, but also a large inflow of the chemicals and sediments which were flushed off streets, yards, parking lots and so on.

Aerial photographs, supplemented by field survey work, are the most reliable source of information on surface cover. Conventional black and white

aerial photographs are quite adequate for most purposes, however, it is often very helpful to use color slides also. These can be taken from a light aircraft with a standard 35mm camera and the total cost is surprisingly small.

Drainage Features: Several types of drainage changes characteristically accompany the development of watersheds. The watershed may be enlarged to accommodate development that extends beyond the drainage divide. Since the size of the watershed has an important influence on the amount of runoff that it produces, such extensions will increase the total water inflow to the lake. Furthermore, since watershed extensions are almost always associated with development, the quality of the added runoff is likely to be poor.

drainage features

Individual drainage channels are frequently subjected to drastic alterations in the face of development. This applies not only to residential and urban types of development, but agricultural development as well. In both cases, streams may be straightened and deepened to increase their flow efficiency. Natural channels are commonly extended into farm fields, along roads and into communities by means of ditching, field tiling and storm sewering. In sum, the changes made in drainage features have two important effects: 1) increasing the total production of runoff from the watershed and 2) increasing the overall flow efficiency of drainage systems. The end result is more poor quality water for the lake.

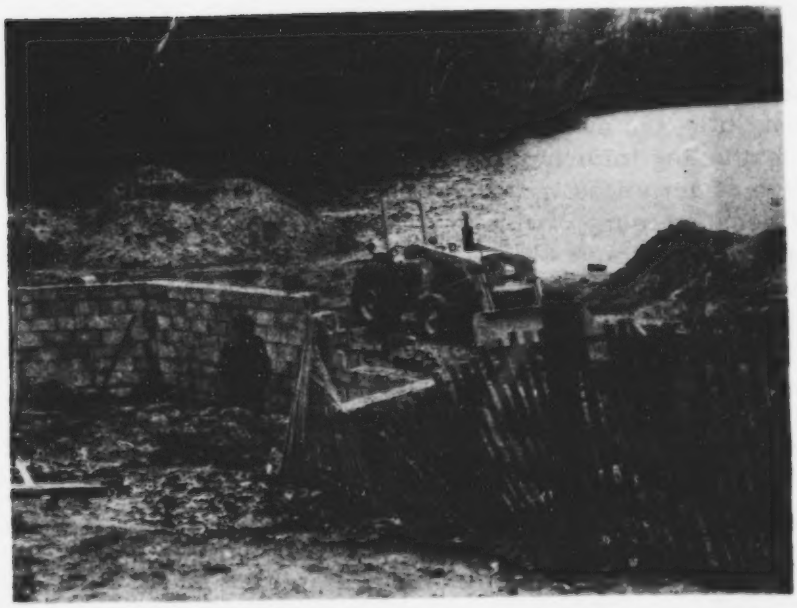
Drainage changes are sometimes difficult to recognize and in some cases municipal, township and county utilities maps can be a helpful starting point for gathering information. However, direct observation of activities in the watershed is always essential because many drainage changes are not recorded by government agencies. Plans for new drains and road construction should be carefully checked for proposed drainage alterations and construction activities need to be observed regularly. In addition, tiling and ditching in and around farm fields, one of the most widespread types of drainage changes, should be duly noted and recorded.

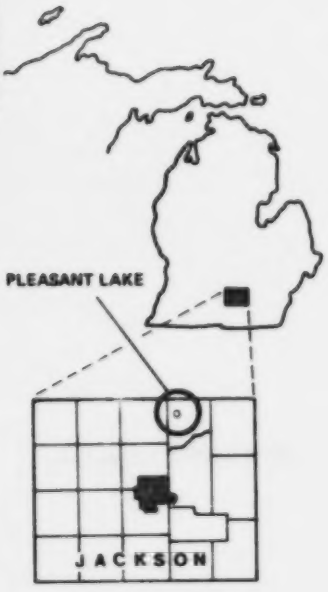
Shoreline: The shorelines of inland lakes are very prone to damage from development and use activities.

shoreline

Where they are weakened by eroding waves or by structures, landowners often fortify shorelines with walls, rubble and concrete. Where they are unsuitable for construction, as in the case of wetlands, they are frequently filled or channelized. The latter changes are known to have especially severe effects on water quality, because the filtering function of the wetland is reduced or lost altogether. In addition, channelization and filling increase the amount of developable shoreline, thereby allowing more land use direct contact with the lake.

Although aerial photography can be helpful in establishing information on the shoreline, direct observation is undoubtably the best means of identifying changes. In fact, the shoreline is probably the easiest feature to observe in the entire lake environment because it can usually be explored by boat. Special care should be taken to record changes in the physical character of the shoreline because certain alterations can only be undertaken with the permission (permit approval) of state or local governments.





AN EXAMPLE: THE CASE OF PLEASANT LAKE

We can illustrate the proposed information approach using a rather typical inland lake in southern Michigan. Pleasant Lake is located in northeastern Jackson County in a rural agricultural area, about ten miles from the City of Jackson. It is accessible to commuters from Jackson and neighboring communities. Presently it is primarily used for recreation and year-round residence.

Most of the shoreland of Pleasant Lake would be classified as bluff or lake slope (see page 54). Along the western shore,

however, the terrain is relatively flat, especially where the shoreline road is closest to the lake. Beyond the shoreland area, in the uplands part of the watershed, the terrain is diversified, ranging from relatively level areas in the north and south to hilly terrain interspersed with wetlands in the east.

present development

The development around the lake is characterized by a band of residential-recreational land use along the shore. The heaviest development occurs along the eastern shore, where cottages have been converted to year-round residences. The remainder of the shore area is less densely developed; however, at the southern end of the lake a number of modern year-round residences have recently been built along a channel that extends about one thousand feet into the watershed. Many of the important features of the Pleasant Lake watershed are shown on the following aerial photograph.

To obtain a systematic set of information about the processes and features in the Pleasant Lake watershed, a method must be designed for recording and organizing observations, data and various types of information. The method described on the following page presents a simple procedure that is intended to serve several important needs:

information objectives

1) Provide an orderly and reliable information and data base

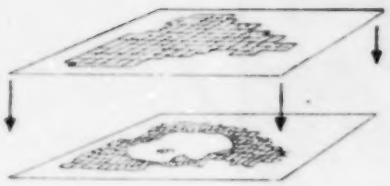
2) Provide a means for systematically identifying change

3) Facilitate the use of methods such as those described in Section IV for analysis of the relationships between changes in the watershed and lake water quality.

A number of methods can be used to provide an organizational framework for geographic data. We have chosen one

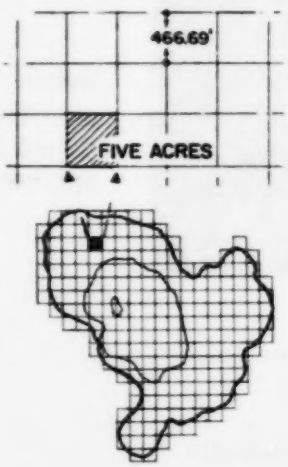
IMPORTANT WATERSHED FEATURES
PLEASANT LAKE

a method for recording information

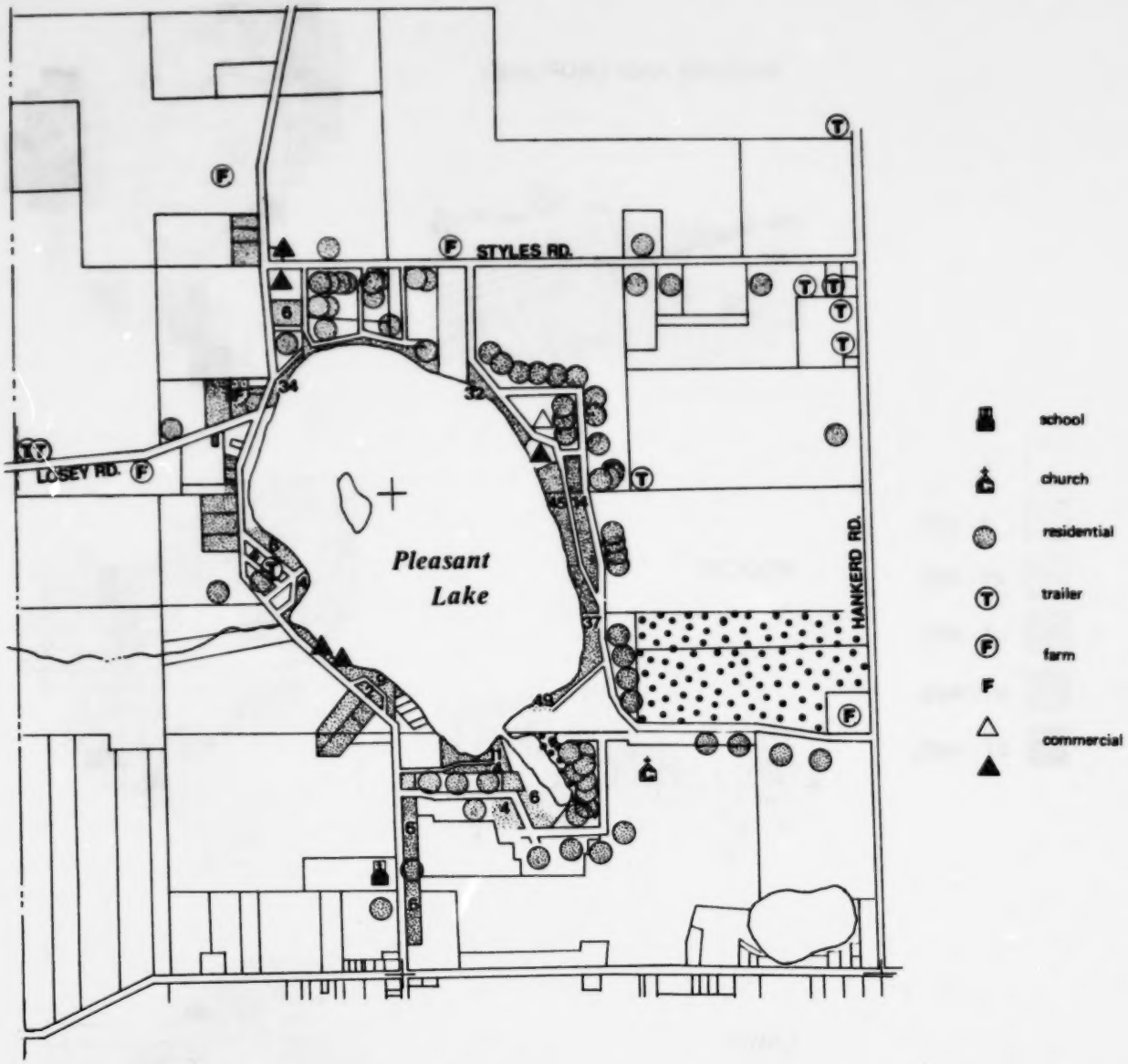


called the grid system because it is not only widely accepted in planning and science today, but requires comparatively little effort to set up and manage. In this system, information is recorded with a grid network that is set over the various maps of the watershed, as illustrated in the accompanying diagram. On each map the grid is adjusted so that it falls in exactly the same position in the watershed. Thus, for example, as it is placed on three different maps showing land use, topography and drainage, each grid square (or cell) always covers the same parcel of land surface. The recorder's job is simply one of 1) transposing the information from each map into the individual cells, or 2) recording in the appropriate cell the results of observations made in the field or information gained from public documents such as development proposals, utilities hearings and building permits.

The size of the cells in a grid system depends on the size of the lake watershed under consideration. In the case of Pleasant Lake, a five acre cell appeared to be an appropriately-sized, yet convenient, recording unit. The accompanying map shows the five acre grid system in position over Pleasant Lake and its watershed. Notice that the perimeter of the grid only approximates the watershed boundary; nonetheless, the actual difference in total area is only about five percent.

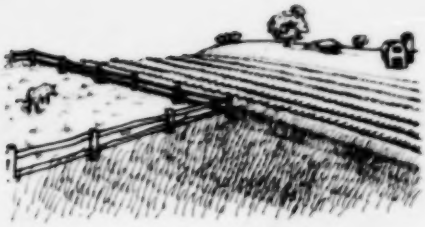


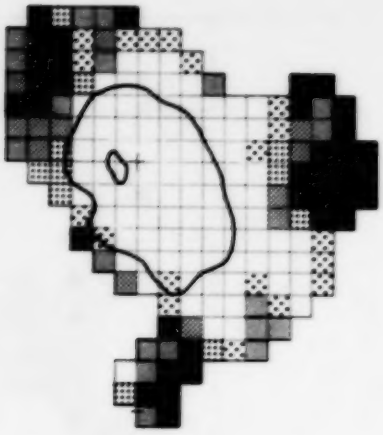
Information on land use in the Pleasant Lake watershed was gained from a land use map produced by the Jackson County Planning Commission. This map is shown on the following page and it is necessary to add that some interpretation was needed before the information could be transferred to the grid system. As for land cover and drainage features, aerial photographs from the Soil Conservation Service, supplemented by field observations, proved to be an adequate source of information.



The following series of maps shows the distribution of land cover types in the Pleasant Lake watershed. In addition, the acreage of each cover type is given.

PASTURE AND CROPLAND





0

1 - 20%

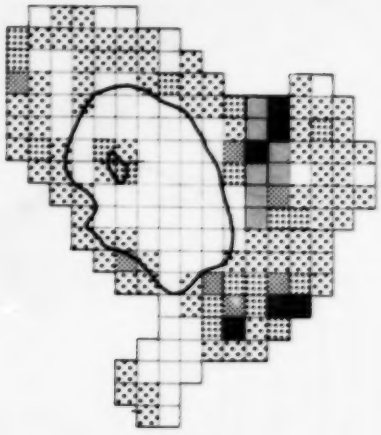
21 - 40%

41 - 60%

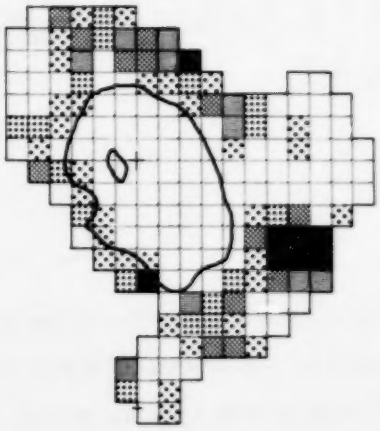
61 - 80%

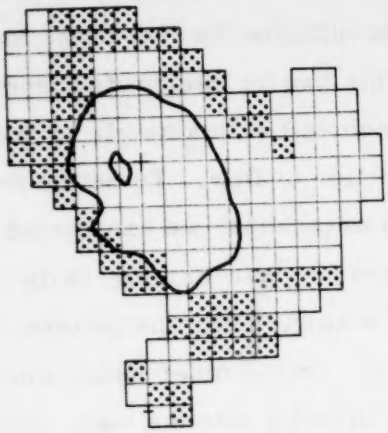
81 - 100%

WOODED

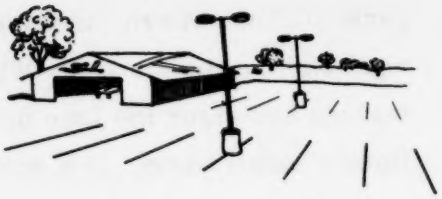


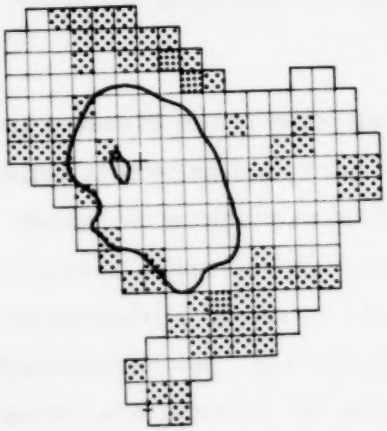
LAWN



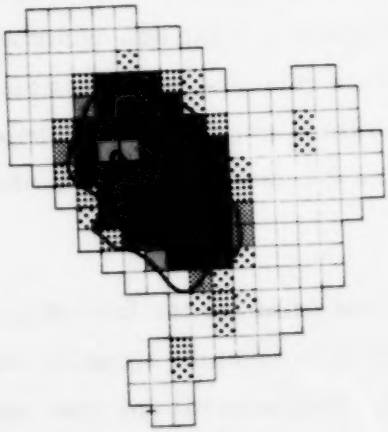


IMPERVIOUS





BARREN



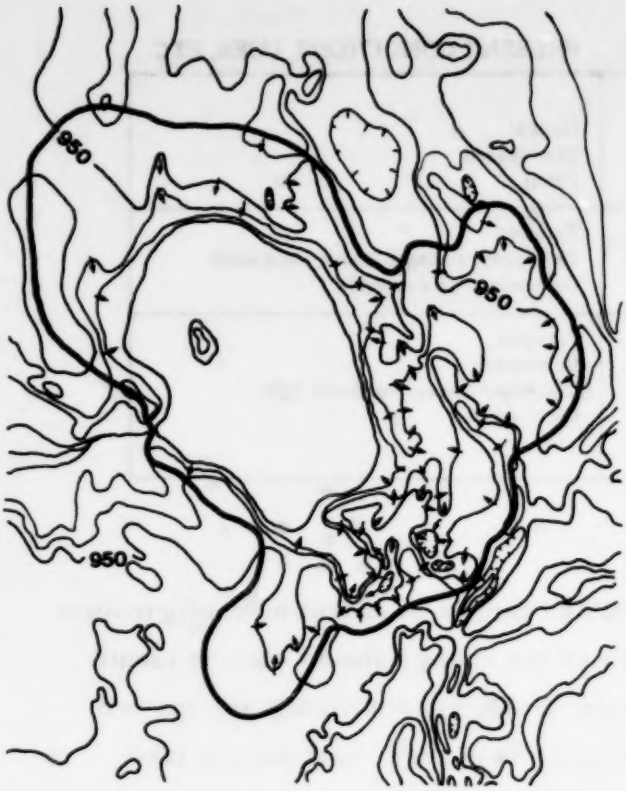
WATER AND WETLANDS

recording the runoff pattern

In addition to recording information from maps and field observations, it is also possible to indicate the flow direction of runoff within each grid cell. This can be interpreted from topographic maps and plotted in each cell with a single arrow representing the predominant direction of flow. To define the general flow pattern for the entire watershed, we can extend and combine the arrows. Where the flows from many cells integrate and enter the lake through a single cell, the pattern defines a small basin, or a sub-basin. On the other hand, where runoff from one or two cells flows directly into the lake, then it is a strong indication that the area is not part of a sub-basin but belongs to the discontinuous belt of land along the shore called the shoreland.

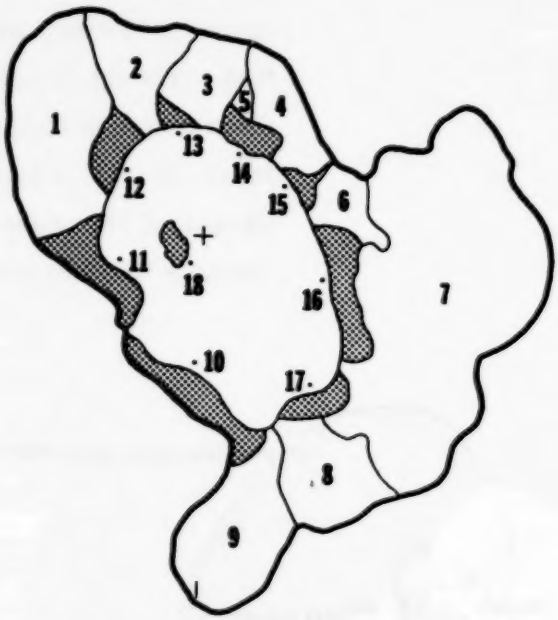
A comparison of the following maps of the Pleasant Lake watershed indicates how well the true runoff pattern is reflected in its gridded counterpart. The first map shows the runoff pattern based on an interpretation of a topographic contour map of the watershed. The second map represents a translation of this pattern into the drainage areas, i. e., shorelands and sub-basins; and the third map shows the entire scheme transposed into the grid system. Although the grid pattern provides only an approximation of the actual drainage pattern, it nonetheless establishes a general framework of the sub-basin and shorelands drainage areas. The characteristics of shoreland and sub-basin drainage areas and their importance in lake watershed management and planning are discussed in detail in the following section of this report.

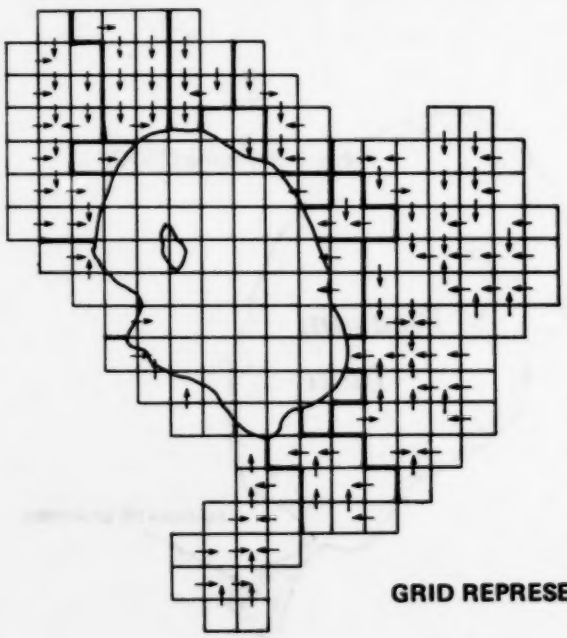
The final items of information relate to the lake shoreline. The configuration of the shoreline and the types of shoreline can be recorded in each cell. Both natural and man-made features can be used to define the shoreline type, for example:



PATTERN OF RUNOFF

WATERSHED DRAINAGE AREAS

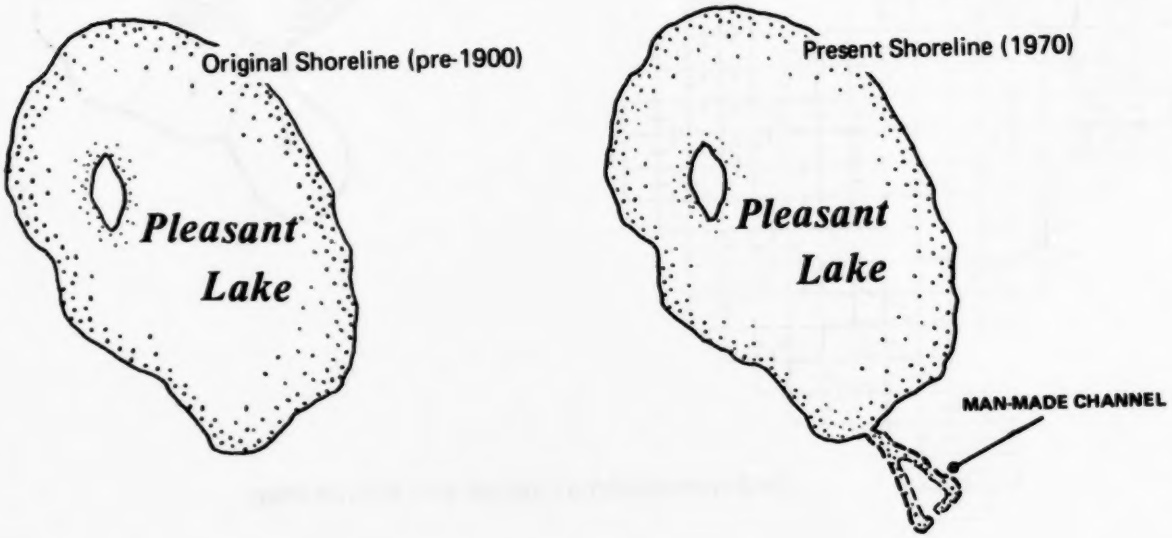




GRID REPRESENTATION OF THE WATERSHED

SHORE TYPE	PRESENT CONDITIONS, USES, ETC.
Wetland	Natural Channelized Filled
Bluff	Forested Developed: cottages, docks, wave walls Deforested and excavated
Terrace	Forested Cultivated Developed: heavy, medium, light Commercial

In addition to recording changes in shoreline configuration on the grid map, the cause of the change should also be identified. Though channelization (dredging) and filling are the two most common causes of shoreline change, variation in lake level, natural erosion and ground subsidence may also be causes of shoreline change. The map below shows the major changes that have been made in the Pleasant Lake shoreline.



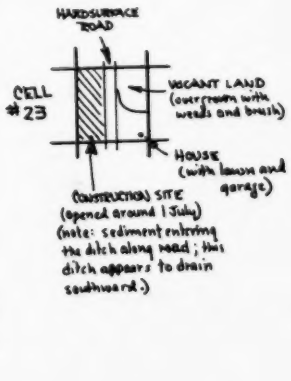
Gaining and recording information on a lake and its watershed can be a very difficult task, especially if the area is large and diversified. Accordingly, it would be unreasonable to expect that the information processes can be initiated and sustained year after year by a handful of concerned citizens. Therefore, it is necessary to recruit organizations in the lake area to share this responsibility. The possibilities are surprising: church groups, 4-H, FFA, high school clubs, school science classes and civic groups such as the Lions, Rotary and Kiwanis. A participating group can be assigned a certain part of the watershed, say, five or ten cells, that it can monitor on a yearly or continuous basis.

As a summary to this section, let us list the steps that should be taken in establishing a working information system for a lake area:

steps involved in building an information system

First: Define the boundary of the watershed. This information is available from the DNR for most large inland lakes. For small lakes, the watershed can be defined from topographic maps.

Second: Construct a grid over the watershed map. Position the grid such that its location can be fixed in the field by landmarks such as roads and buildings. The size of the individual cells can range from three to ten acres, depending on the size and diversity of the area.


HARD SURFACE ROAD
CELL #23
VACANT LAND (overgrown with weeds and brush)
HOUSE (with lawn and garage)
CONSTRUCTION SITE (opened around 1 July)
(note: sediment entering the ditch along road; this ditch appears to drain southward.)

Third: Collect data and information from existing sources, such as land use maps and aerial photographs, and record it on the grid system. This may be done by marking the area of each cell occupied by a certain feature or making a note on the grid describing the feature.

Fourth: Assign responsibilities to groups and individuals for monitoring certain cells.

Fifth: Record observations at least once a year with an eye to these questions:

key questions for reviewing change

1. Have there been land use changes?
2. Have there been surface cover alterations? Are there areas of exposed soil?
3. Have there been alterations of the shoreline:
   a. channelization?
   b. filling?
   c. construction of shore protection facilities such as wave walls?
   d. removal of shoreline vegetation?
4. Have there been soil alterations such as mining, filling and grading?
5. Have there been any changes in the drainage features:
   a. new storm sewers or sanitary sewers?
   b. ditches and tiles in farm fields?
   c. streets, curbs and gutters?
   d. any new areas of standing water?

Sixth: Consolidate data and information into an orderly record using a format such as the table below.

CELL	Cover	Use	Drainage	Shorelines	Problems	Miscellaneous
1						
2						
3						
4						

Once and information record has been established on the

features and changes in a lake area, what can be done to produce some planning and management action? The answer depends in part upon the professional services available from governmental agencies in the area. As a first step, the local county or regional planning agencies should be contacted to learn whether staff personnel can help in organizing a planning and management program. County planning agencies are active in the urbanized areas of the State and regional planning agencies are active throughout the State. Each region is comprised of a number of counties and the regions are shown in the map below. Appendix B gives the names and addresses of each regional planning office.

In some counties and planning regions, professional planners or environmental specialists may be available to help organize and lead a lake area planning program, whereas in other regions the responsibility may be shared with the DNR. The Inland Lake Management Unit in the Division of Land Use Programs is the appropriate DNR organization to contact for lake planning and management assistance. This Unit has already launched the self-help water testing program and the DNR is hopeful that its services can be extended to the watershed as well.

section 3

Differentiation of the watershed into sub-basins and shorelands

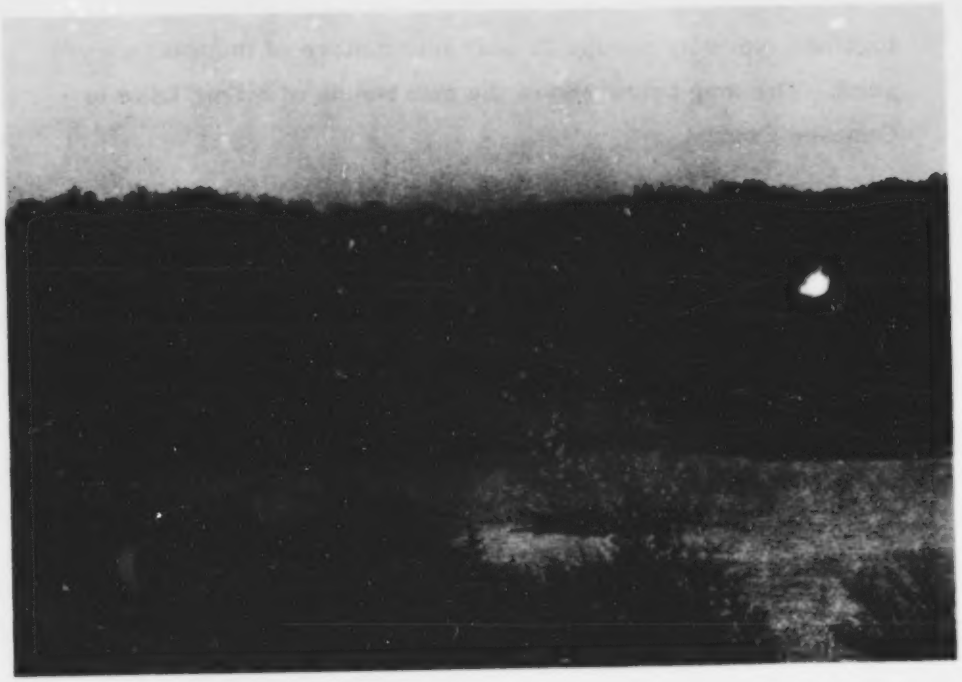
Classification of shorelands

Development capacity of shorelands

Discharge from sub-basins

Formulation of the sub-basin influence factor

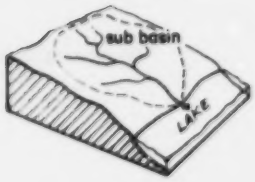
Ranking sub-basins for planning and management considerations



WATERSHED ANALYSIS

INTRODUCTION

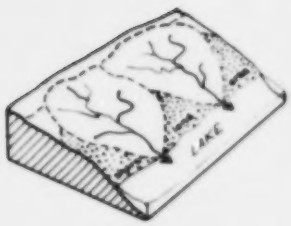
Within the watershed of nearly every inland lake, two types of drainage areas can be defined. These we have chosen to call sub-basins and shoreland. Sub-basins are small watersheds nested within the larger watershed of the lake. Although they are often drained by a small network of streams, it is not uncommon to find sub-basins drained by wetlands, gullies, storm sewers and ditches as well. Certain features, however, are characteristic of most sub-basins. First, they are bounded by a drainage divide which separates them from adjacent drainage areas. Second, most tend to be leaf-shaped with the narrow part of the basin, i.e., the mouth, attached to the lake itself. Third, sub-basins usually span the entire breadth of the watershed and



sub-basin features

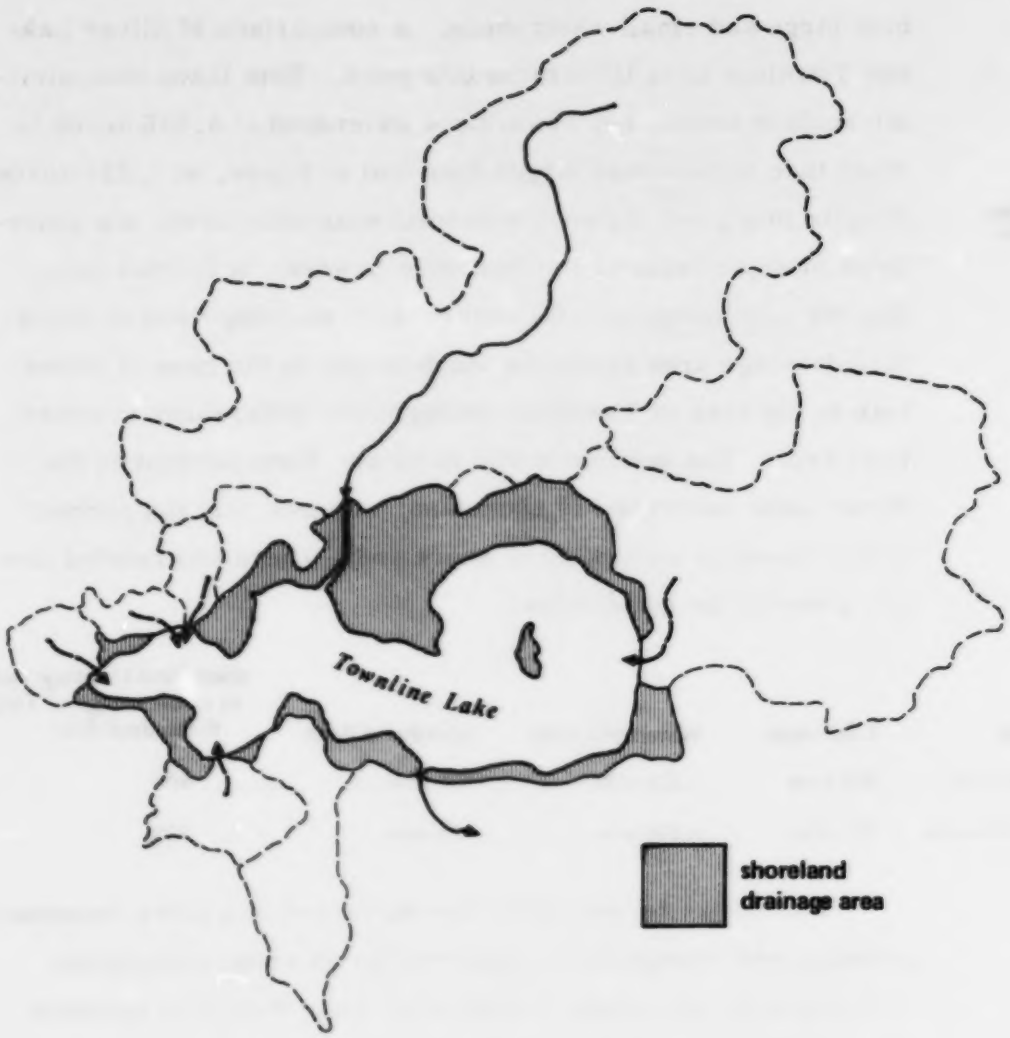
together typically occupy 75 percent or more of the total watershed. The map below shows the sub-basins of Silver Lake in Genesee County.

SHORELAND DRAINAGE AREA



shoreland drainage

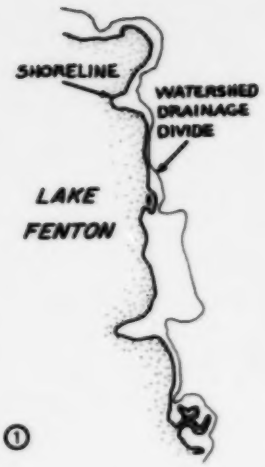
Owing to their leaf-shape, it is impossible for sub-basins to occupy an entire lake watershed. From headwaters to mouth, sub-basins become narrower, and at a distance of about half way to the lake the mutual drainage divide of two adjacent sub-basins usually splits into separate divides. An area is thus opened between the sub-basins which drains directly into the lake. Around most lakes, these areas take the form of a discontinuous belt of shoreland. The following illustration shows the shoreland drainage area for Townline Lake in Montcalm County. As a drainage area, this land is markedly different from sub-basins not only in shape and total area, but also in the nature of water movement across it. Runoff tends to move toward the lake along individual paths formed by gullies, ditches, yard tiles, driveways and streets. This presents a knotty lake management problem because water from this area enters the



lake at hundreds or thousands of points along the shore. The problem is compounded due to the fact that the shoreland is normally the most intensively developed area of the watershed.

shoreland as a development area

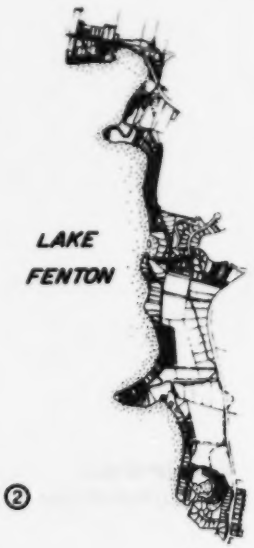
Let us examine the shoreland drainage area in greater detail. For lakes of a given size and shape, the proportion of a watershed made up of shoreland is generally independent of watershed size. In other words, it appears that for lakes of similar dimensions, shoreland area is often about the same for



①

both large and small watersheds. A comparison of Silver Lake and Townline Lake illustrates this point. Both lakes have similar surface areas, but Townline's watershed at 4,436 acres is more than three times larger than that of Silver, at 1,224 acres. Despite this great difference in total watershed area, the shorelands of these lakes are comparable in area. It follows then, that the percentage of total watershed area comprised of shoreland drainage area should be much larger in the case of Silver than in the case of Townline, owing to the differences in watershed area. The data show this to be so; forty percent of the Silver Lake watershed is shoreland, whereas only ten percent of the Townline watershed is shoreland. These and related data are given in the table below.

Lake	Lake Area	Watershed Area	Shoreland Area	Shoreland Drainage Area as a Percentage of Total Watershed Area
Silver Lake	848 acres	1,224 acres	500 acres	40%
Townline Lake	707 acres	4,436 acres	451 acres	10%



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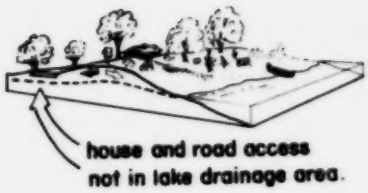
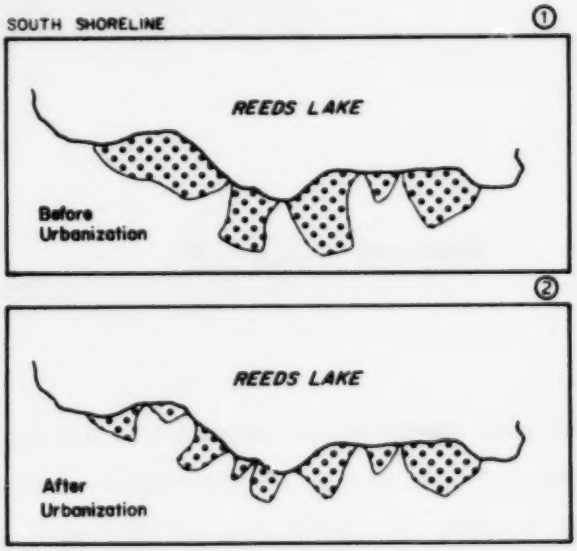
In relative terms, then, the shoreland is a more important planning and management consideration on small watersheds. For example, in a study conducted on Lake Fenton in Genesee County, it was learned that nearly the entire watershed on the east shore is shoreland, much of which is less than 500 feet wide. This area is shown on the first map on the left. The second map shows the residential development in the same area. The land use planning implications are clear. Much of the residential development on this side of Lake Fenton could have been located outside of the drainage divide without the loss to property owners of desirable frontage contact with the lake. The following sketch entertains the concept of a residential setback distance adjusted to the location of the watershed drainage divide. With houses and cottages situated behind the divide, poor quality

drainage from yards, roofs, streets, lawns and septic drain fields is restricted from direct entry to the lake.

In urbanized areas, shoreland drainage areas are often subjected to major changes in size. It appears that as development progresses, the shoreland area tends to shrink as more and more of it is taken up by storm sewer sub-basins. This trend is evident on Reeds Lake in Kent County where the city of East Grand Rapids has extended the storm sewers into the shoreland drainage area on the south side of the lake. Two types of encroachment are evident here: 1) new sub-basins have been created which cut through the shoreland to reach the lake and 2) sub-basins behind the shoreland have been expanded toward the lake. As a result, the belt of shoreland has become shallower and more fragmented with urbanization. The maps below show the pre-urban (Map 1) and urban (Map 2) patterns of shoreland drainage areas on the south side of Reeds Lake.

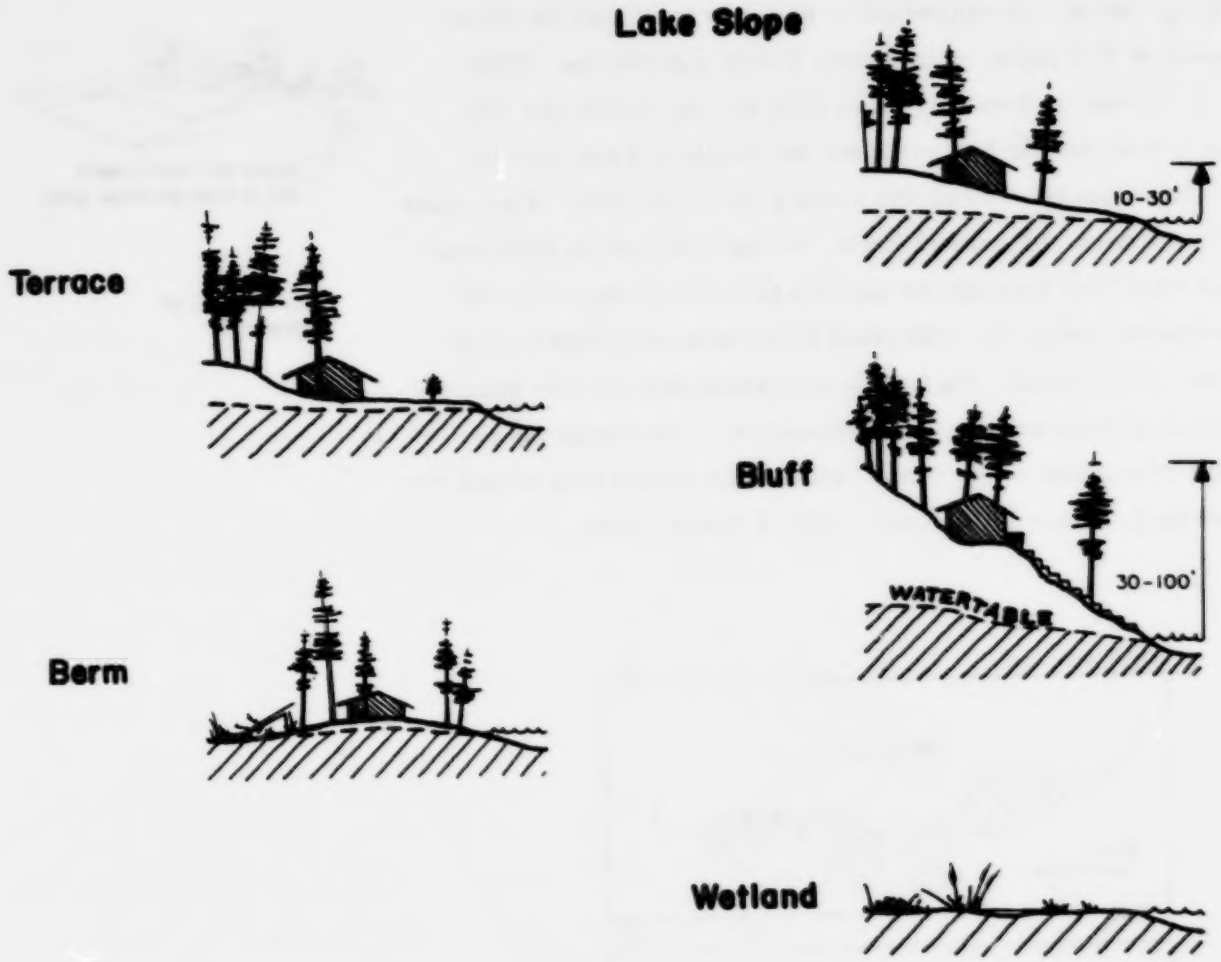


urbanization of shorelands



shoreland types

Around almost every lake a number of different types of shoreland can be defined. We have identified five main types on the basis of topography and drainage and they are shown below.



wetland

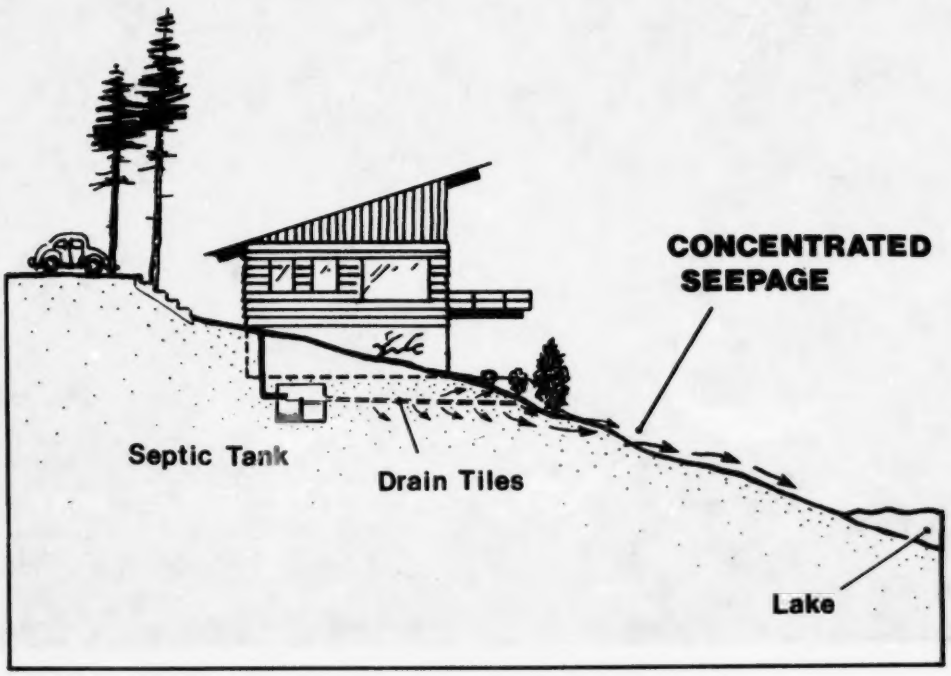
Wetlands pose the greatest limitation to development for several reasons. First, because of the high water table, they are singularly unsuited for septic disposal systems. Second, in order to build on them, landfill is required which destroys the wetland and eliminates its ecological role in the lake system.

The berm type shoreland is somewhat more suitable for development, especially if it is high and wide. Small berms, however, present many of the same problems as wetlands. In addition, lakeshore roads are often routed along berms and development is sandwiched into small lots along the shore. This places houses, cottages, septic drain fields and human activities in general much too close to the lake, resulting in deterioration of water and shore.

berm shoreland

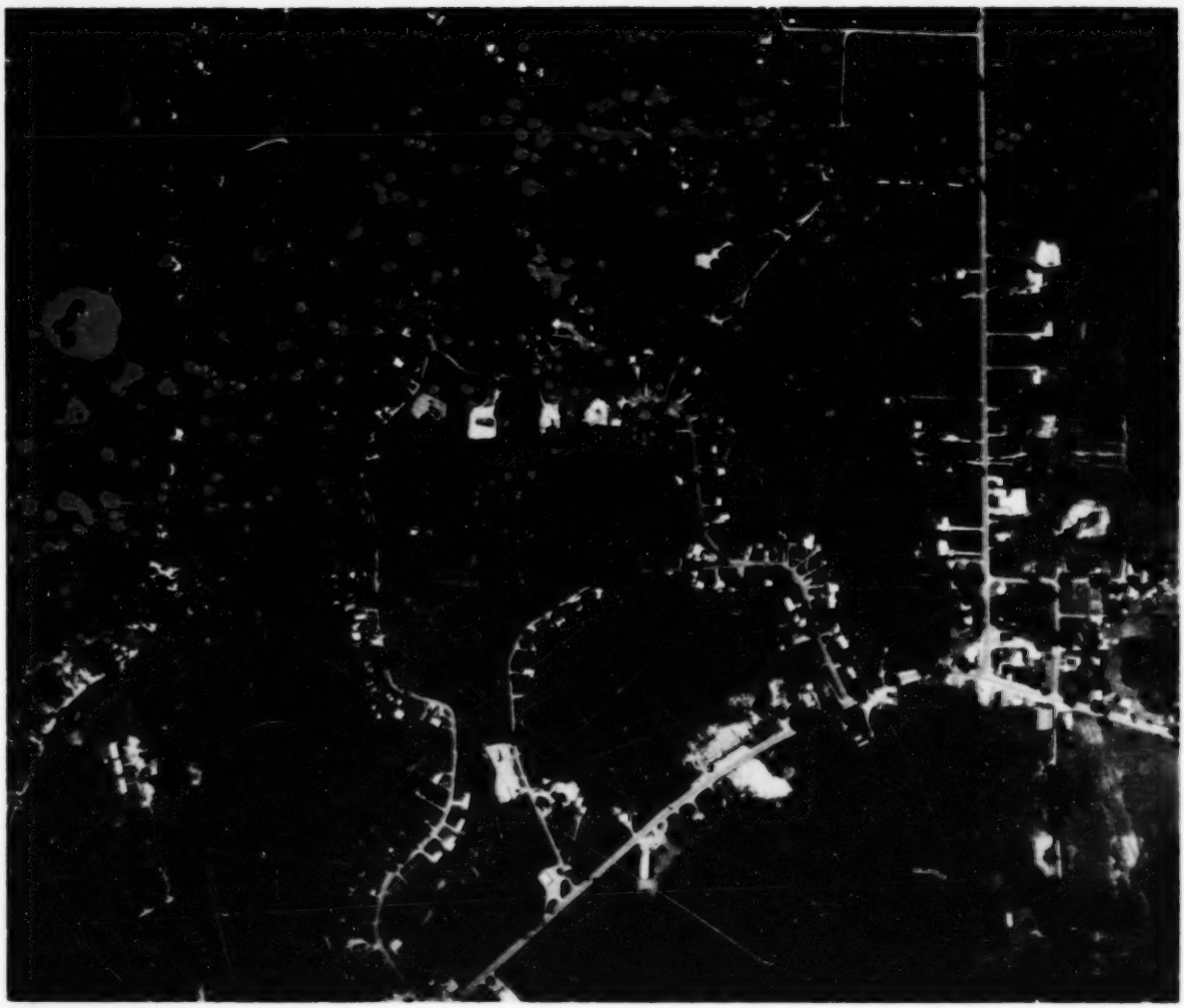
The lakeshore bluff can be a highly attractive building site, and if properly planned, development of such shoreland may have little negative influence on the lake. If, however, bluffs are developed in the conventional manner, they can be problematic. For instance, as construction sites they are very prone to rapid runoff which can produce severe soil erosion and sedimentation of lake water. Moreover, conventional septic fields will malfunction if placed on the bluff and, as the diagram shows, this can result in seepage of contaminated water to the lake.

bluff shoreland



lakeslope and terrace shoreland

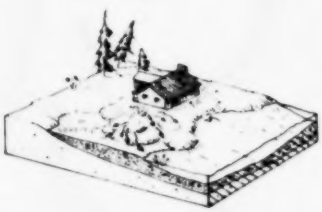
The remaining two shoreland types, namely the terrace and the lake slope, are comparatively well suited for development. This is not to say that they are safe from the problems caused by development, as the following aerial photograph indicates. Indeed, indiscriminate development of these shorelands can produce all the problems mentioned above. In general, however, they offer the sites which are least susceptible to deterioration from modern development.



shoreland development trends

There is a sequence of land use development on inland lakes that is related to shoreland types and it can provide us with some insight into a fundamental lake planning problem. Development usually begins on shoreland where the sites require little in the way of physical improvements such as excavation, filling and shoreline reinforcement. As development advances along the shore, less favorable sites such as wetlands and low berms are encountered, but initially they are bypassed as building sites. Eventually all the good lake slope and terrace sites are taken and prospective property owners begin to look toward nearby wetlands and other unfavorable sites for development.

Although these are less pleasing as home and cottage sites, landowners are willing to build on them because their investments are protected by the substantial values of neighboring properties situated on better sites. But wetlands, low berms and bluffs pose such serious limitations to development that necessary site improvement usually demands a considerable investment. Unhappily, the record shows that the level of investment committed to the improvement of such shorelands is usually insufficient to insure against serious environmental deterioration. The outcome is too clear. Rundown property, coupled with declining lake quality, spell certain erosion of lake property values, all of which may eventually lead to degeneration of the entire lake community.



the concept of shoreland development capacity

What can be done to avoid this depressing cycle? The first order of business is to gain some information on the physical character of the shoreland. The development capacity of the shoreland of a lake can be estimated on the basis of the shoreland classifications outlined earlier. The various types of shorelands can be grouped into three orders. First order

first order

second order

third order

shoreland is made up of terrace, lake slope and high berm sites, none of which require improvement for development. Second order shoreland has distinct development limitations but with proper planning and design considerations they may be overcome in some places. Bluffs are an excellent example of second order shoreland. Sites with severe development limitations are third order shoreland. This includes mainly wetlands and low berms. As a general rule, the more improvement that is necessary in order to develop a site, the lower the order of the site.

If it is found that the existing development on a lake occupies all first order sites, then it is safe to say that the development capacity of the shoreland has been reached. Some development of second order sites can be viewed as acceptable if there has been adequate planning to compensate for site limitations. For instance, development of a bluff site should include substantial building setback from the shore, as well as specially designed auto access and septic system drainage. If houses, cottages and related facilities are found on third order sites as well, then the development capacity of the shoreland has been exceeded.

By way of example, let us classify the original shoreland of Townline Lake into first, second and third order development sites and then compare the map with the present pattern of development around the lake. This should give us an indication of future development potential of the shoreland area of this lake.

As the map on the left shows, nearly all of the first order sites and a small percentage of the second order sites have been developed. In addition, there are distinct signs that site improvement projects have begun on third order sites. These appear in the form of channels which cut into wetlands. What is the drawback of site improvement with channels? First, the

lake shoreline is greatly lengthened by the presence of a channel, thereby allowing more development at the water's edge. Second, soil drainage along the channel is often inadequate for proper filtration of septic wastes. Third, circulation in the channels is poor, often leading to water stagnation, algae blooms and other aquatic plant problems.

SUB-BASIN DRAINAGE AREA

the linkage concept

In general, very little of the perimeter of any sub-basin borders directly on the lakeshore. As a result, we may at first tend to underestimate the significance of sub-basins in lake planning and management. But when we realize that the land drained in sub-basins is linked to the lake by a flow system, it is easy to appreciate that the most remote land in the watershed can be only minutes of flow time from the lake.

sub-basin influence on the lake

There are two primary concerns in evaluating relative influence of a sub-basin on an inland lake:

1. How much surface water does it contribute to the lake?
2. What is the quality of that water?

In its natural state, each sub-basin has the capability of producing a certain amount of surface runoff from a given amount of rainfall. The actual quantity of runoff, called discharge, is controlled by many factors, but we can approximate it on the basis of three measurements:

determination of sub-basin discharge

1. The coefficient of runoff, which is an indication of how much water is left on the surface after the soil has soaked up its share. (c)
2. The intensity of rainfall; that is, how much rain falls per hour. (I)
3. The area of the sub-basin. (A)

Discharge (Q) is computed according to the formula:

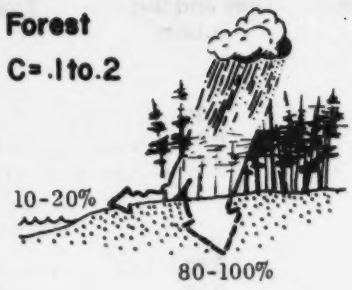
$$Q = c\,I\,A$$

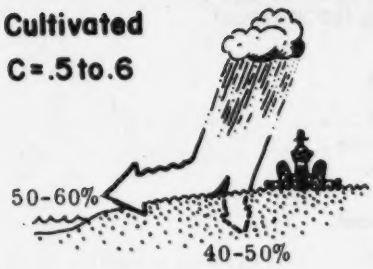
the coefficient of runoff

The coefficient of runoff is an especially critical factor, for among other things, it is the one control on runoff that we can change drastically by simply varying the surface cover of the land. For example, if a parcel of land is converted from forest to residential, the coefficient of runoff can double. This means that under residential use, the discharge produced from any rainstorm will be twice what it was under forest cover. In addition, the quality of the discharge from residential land is much poorer than that from forested land, owing, of course, to the abundance of foreign residue deposited on the surface by human activities.

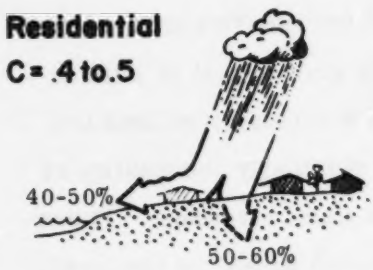
Because the coefficient of runoff is such an important element in the problem of sub-basin runoff, it is essential at this point to examine it somewhat further. It is generally agreed that most forested land in the Great Lakes region generates virtually no surface runoff from the average rainfall and only small amounts of runoff from the intensive summer thunderstorms. This is due to the fact that the trees are good regulators of the movement of rain water to and over the ground. First, they intercept much of the rain; second, they loosen the soil particles and thereby hasten the percolation of water into the soil. With these processes in mind, it is easy to envision the changes in runoff that take place when the forest cover is removed from a watershed.

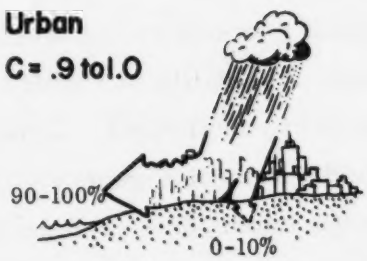
The following illustrations attempt to convey the idea of the coefficient of runoff as it is related to land cover. The arrow extending into the soil represents the percentage of rainfall lost to the soil and the arrow extending across the surface represents the percentage of the rainfall which runs off the surface. The coefficient of runoff is simply the latter percentage expressed in the form of a decimal.





common coefficients of runoff





Although an estimate of the coefficient of runoff can be made on the basis of cover alone, it is necessary to take soil texture and slope into consideration if an accurate coefficient is desired. Soil texture refers to the size of the particles in a soil. Generally, the larger the soil particles the faster the soil can receive water. Thus, sandy soils are usually associated with low coefficients. Slope refers to the steepness of hill sides and, of course, the steeper the slope, the higher the coefficient of runoff.

estimating the runoff coefficient

The following table gives the coefficients for some common rural surfaces based on cover, soil and slope.

Topography and Vegetation	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat (0 - 5% slope)	0.10	0.30	0.40
Rolling (5-10% slope)	0.25	0.35	0.50
Hilly (10-30% slope)	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82

the coefficient of runoff as an indicator of water quality

The final point to be made about the coefficient of runoff is its relationship to water quality. In general, it is safe to say that the coefficient increases as the intensity of land use increases. It is also safe to say that generally the quality of runoff declines as the intensity of land use increases. Therefore, the quality of runoff can be expected to fall as the coefficient of runoff rises. This is related to two facts: 1) intensive human activities generate large amounts of surface residue and 2) the impervious surfaces associated with intensive land uses generate fast-flowing runoff that flushes the residue from the land. Carried to the lake, these residues constitute a serious source of pollution.

What sorts of contaminants are found in the runoff from developed areas? Scientists working in the Traverse Bay area found that runoff from residential areas was heavy in chemical, physical and bacterial contaminants. The following data are based upon measurements made of discharge from a sixty-three acre area 10, 20 and 50 minutes after the onset of a summer

rainstorm. Notice, in particular, the heavy concentrations of the bacteria fecal coliform and fecal streptococci.

An Example of Quality of Runoff from a Residential Area

Date of Storm: 7/20/72
Typical Discharge: 2.67 cfs
Drainage Area: 63 acres
Duration of Storm: 90 min.

Parameter	10 min.	20 min.	50 min.
Ammonia Nitrogen (mg. per liter)	.92	.82	.46
Nitrites (mg. per liter)	.015	.014	.004
Nitrates (mg. per liter)	.48	.63	.25
Phosphate (mg. per liter)	.29	.33	.09
Total Coliform (col. per milliliter)	77,000	*	27,000
Fecal Coliform (col. per milliliter)	55,000	**	**
Fecal Streptococci (col. per milliliter)	47,000	47,000	33,000
pH	7.5	7.7	7.9
Tubidity (JTU)	65	85	35
Alkalinity (mg. per liter)	96	114	201
Total Solids (mg. per liter)	----	457	367
Suspended Solids (mg. per liter)	444	525	77.8

* Confluent
** Too numerous to count

(From Gannon and Meier, 1972)

To most of us the raw data are not very meaningful; however, compared to State of Michigan water standards this discharge must be rated unsafe for partial bodily contact. In other words, it would not be advisable to touch this water.

To return to our question concerning the quality of water produced by sub-basins, we can provide only a general answer and say that overall it decreases as the coefficient of runoff increases. Regarding the question of how much water the sub-basin produces, however, we can be somewhat more definite. By combining soils, slope and cover information with sub-basin area and rainfall intensity, we can compute the total discharge

for a given rainfall. With a runoff value and a knowledge of the land use for each sub-basin of a lake watershed, a relative influence factor can be assigned to each sub-basin. However, before we can use such an influence factor, the effect of connectivity must be assessed for each sub-basin. That is, some evaluation must be made of the efficiency of drainage linkage between sub-basin and lake. If, for example, no drainage channels connect the bulk of a basin to the lake, then the movement of runoff may be slow and much of the water may be lost enroute to seepage and evaporation. On the other hand, if the basin is interlaced with channels which together form an efficient flow network that is connected directly to the lake, little water is lost enroute to the lake. The influence factor is maximized, of course, for those sub-basins which have the capability to: 1) generate large discharges of low quality and 2) move discharge to the lake with little water loss.

the concept of an influence factor for sub-basins

Sub-basins may be classified into six categories according to the efficiency of their drainage systems. The most efficient system is one comprised exclusively of storm sewers; whereas the least efficient is one with no discernible network of surface channels and poor linkage with the lake. Intermediate are those which drain via the natural streams, intermittent channels (ravines and gullies) and wetlands. The illustrations on the right attempt to show the nature of each basin type beginning with the most efficient.

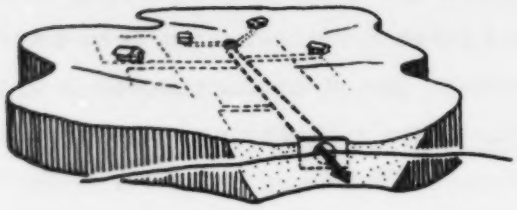
sub-basin types based on flow efficiency

In theory, it should be possible to compute the influence factor of each sub-basin by mathematically integrating discharge, water quality and network efficiency. However, the methods are presently not available to compute a quantitative expression for either water quality or flow efficiency. (This is true only for natural networks such as wetlands and inter-

SUB-BASIN TYPE

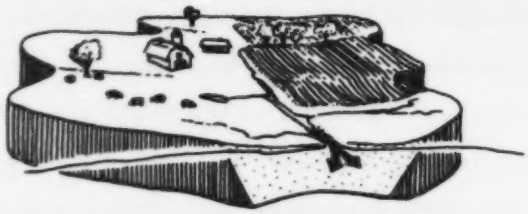
FLOW EFFICIENCY

Storm Sewer

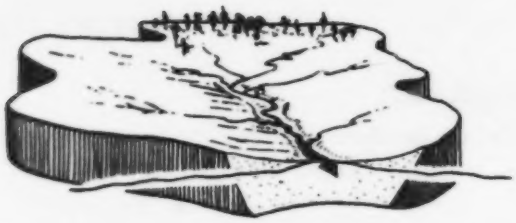


Most Efficient

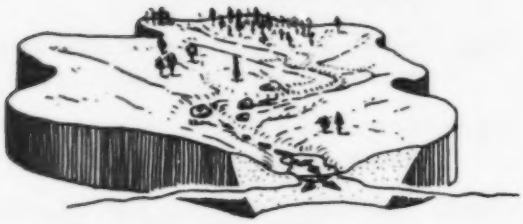
Improved Channel



Natural Stream

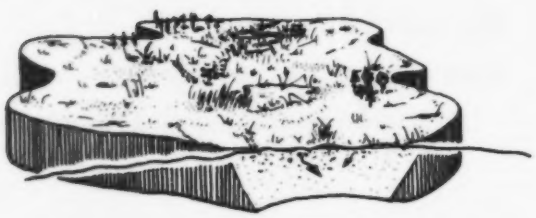


Intermittent Stream



Wetland

Diversified



Least Efficient

mittent streams. The efficiency of storm sewers, open drains and perennial streams has been determined by hydraulic engineers). But since our purpose is to identify the relative influence of the sub-basins in a watershed rather than predict the amount of influence of individual sub-basins, we can assign dimensionless values to these factors. The values or coefficients can be scaled according to the range of intensities that are associated with each factor; for example, the highest coefficient assigned to the most intensive and the lowest value to the least intensive. The following tables offer a set of coefficients for water quality and flow efficiency.

purpose of the influence factor

WATER QUALITY COEFFICIENTS

Land Use	Coefficient
Urban (either industrial, commercial institution or a mixture of all three)	1.0
Urban Residential (mainly medium and high density residential)	.8
Suburban (low density residential with 25% or less open and wooded)	.6
Agricultural (mainly cultivated with 25% or less fallow and wooded)	.6
Rural Non-Cultivated (mixed vacant, wooded, pasture and residential)	.2
Forest (75% or more wooded)	.1

coefficients of water quality and flow efficiency

FLOW EFFICIENCY VALUES

Drainage Network	Coefficient
Storm Sewers	1.0
Improved Channels	.8
Perennial Streams	.7
Intermittent Stream Channels	.5

(table continued on following page)

Wetlands..... .3

Diversified..... .1

In areas of diversified terrain and land use, the values of these coefficients are usually highly variable from one sub-basin to another. The Reeds Lake watershed is a good example. As is shown in the drainage features map on the following page, the area directly south of the lake has been intensively storm sewered by the City of East Grand Rapids. Most of the sub-basins in this area not only have the highest possible flow efficiency coefficient (1.0), but as the land cover map reveals (following page), they also have high coefficients of water quality and runoff. In contrast, the eastern half of the watershed is much less developed and sizeable tracts of forest and wetland can be found in the two large sub-basins that drain the area. Although a limited number of storm sewers and open drains have been built in the upper parts of these sub-basins, the trunks of both remain largely "unimproved". As a result, the runoff from the upper parts of the sub-basins must pass through wetlands and natural channels where it is filtered and partially dissipated before reaching the lake. This, of course, is in sharp contrast to the storm sewered sub-basins in the urbanized part of the watershed, where runoff is transmitted to the lake in a form little changed from that which originated on the parking lots, yards and roofs.

examples of water quality and flow efficiency

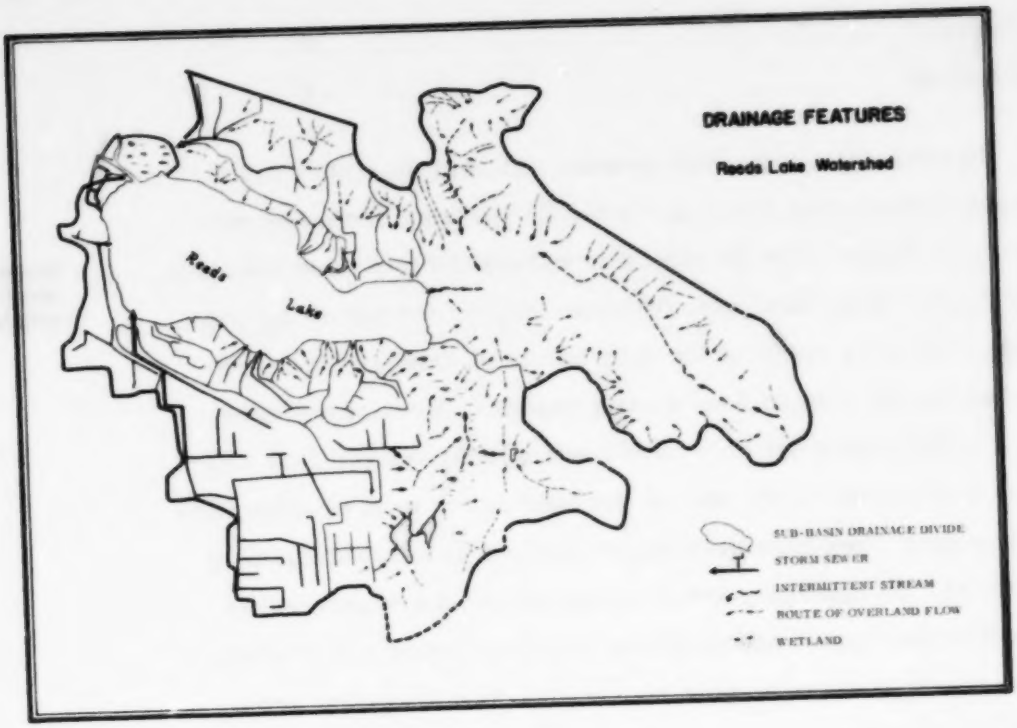
Though admittedly crude, these coefficients do allow us to compute an influence factor for each sub-basin in a lake watershed:

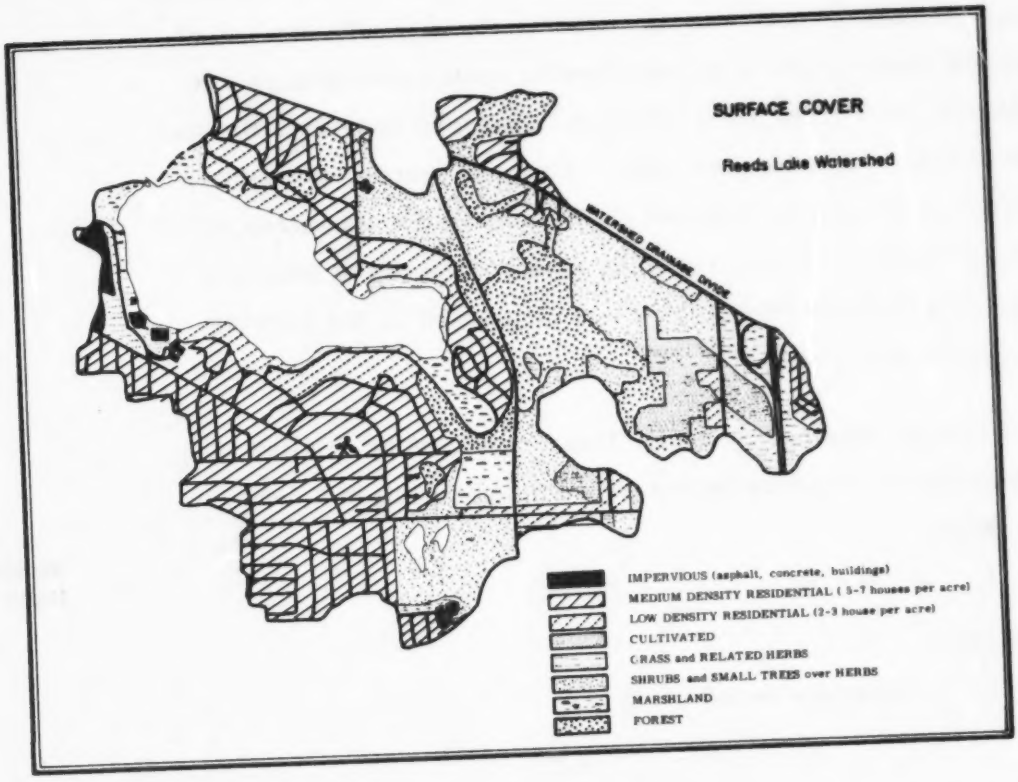
$$I_f = Q \cdot W \cdot E$$

the influence factor formula

in which:

I_f = influence factor


DRAINAGE FEATURES
Reeds Lake Watershed
Reeds
Lake
SUB-BASIN DRAINAGE DIVIDE
STORM SEWER
INTERMITTENT STREAM
ROUTE OF OVERLAND FLOW
WETLAND


SURFACE COVER
Reeds Lake Watershed
WATERSHED DRAINAGE DIVIDE
IMPERVIOUS (asphalt, concrete, buildings)
MEDIUM DENSITY RESIDENTIAL (5-7 houses per acre)
LOW DENSITY RESIDENTIAL (2-3 house per acre)
CULTIVATED
GRASS and RELATED HERBS
SHRUBS and SMALL TREES over HERBS
MARSHLAND
FOREST

Q = discharge, cfs.

W = water quality coefficient

E = flow efficiency coefficient

Based on the influence factors, planning and management priorities can be assigned to the sub-basins of a watershed. The sub-basin with the largest influence factor should be given greatest immediate attention, whereas the one with the smallest influence factor should be given the least immediate attention. An additional step is necessary, however, before actual priorities can be assigned. This involves evaluating whether a planning or management program is most appropriate for each sub-basin.

planning or management designation

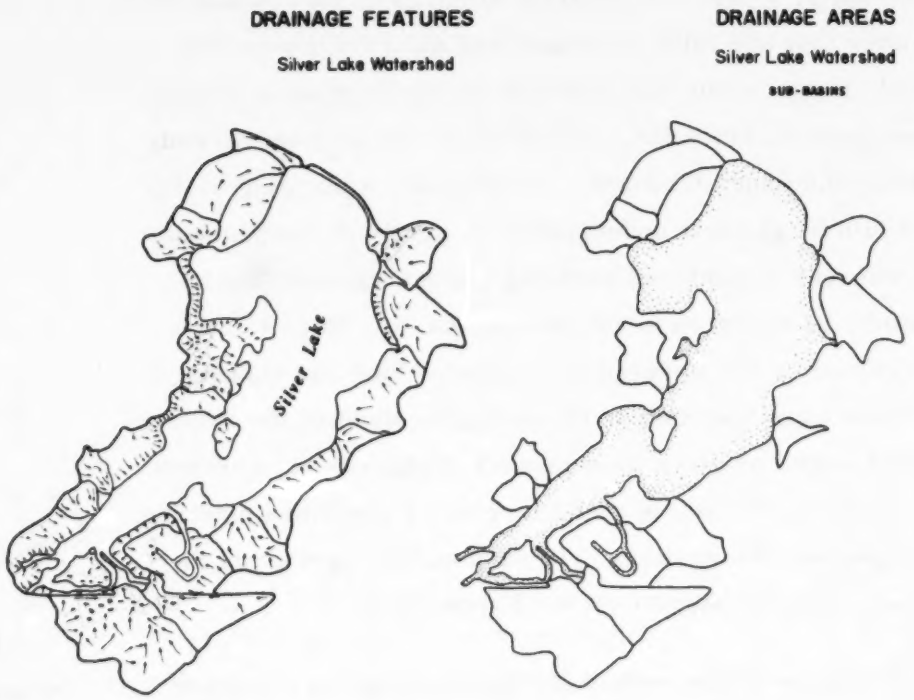
The question of whether a sub-basin should be given planning or management designation can be answered on the basis of the intensity, extent and apparent stability of its present land use. Those that are fully developed and show little evidence of overall change in current land use should be given a management designation, since their influence on the lake has already been established and stabilized. In contrast, a planning designation would be given to undeveloped or lightly developed sub-basins; whereas a combined planning and management designation would be assigned to sub-basins that are 25 to 75 percent developed or are undergoing extensive land use change. In the Reeds Lake watershed, for example, most of the eastern sub-basins would be given management designations, whereas the two western sub-basins would be given a combined planning and management designation. The map on the right gives the various sub-basin designations for Reeds Lake.

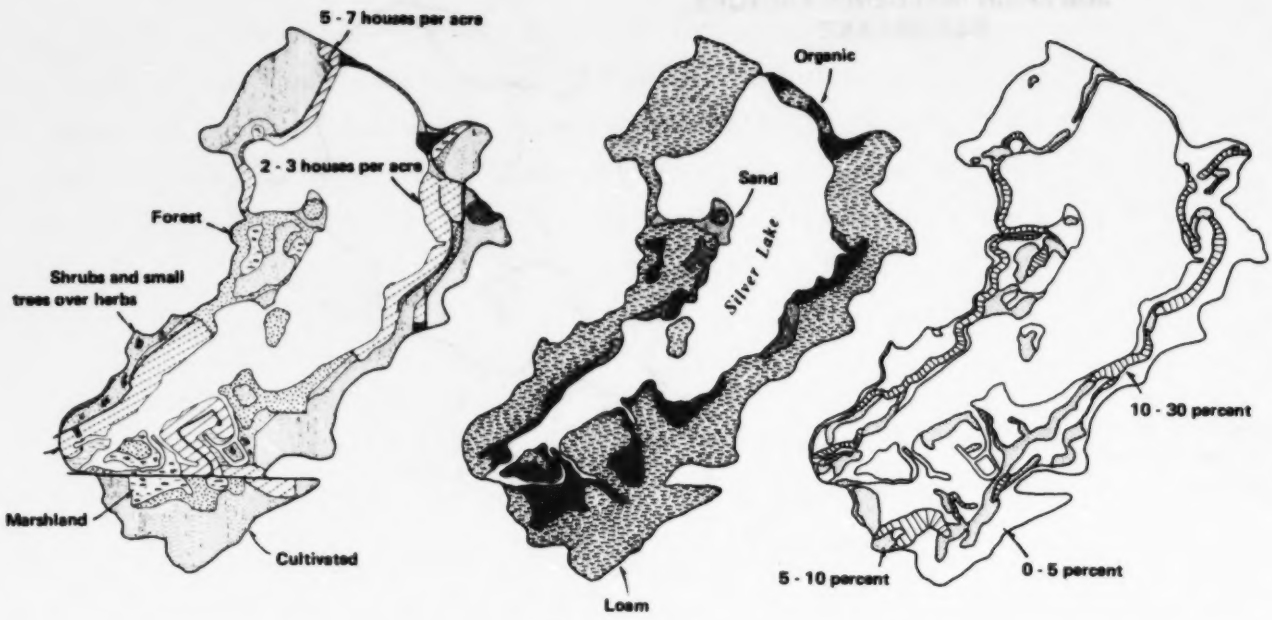
Application of the method for determining the influence factor requires certain information about each sub-basin. The sources of environmental information and a system for recording

it were discussed in previous sections of this report. Suffice it to mention here that suitable information for most lake areas of the State can be gained from topographic maps, aerial photographs and soils maps. These provide data on slope, drainage features, drainage divides, soils, land cover and land use. With a little interpretation, these data will yield information on 1) the coefficient of runoff, 2) flow efficiency, and 3) the general quality of runoff. Let us use Silver Lake as a case example.

review of the sub-basin analysis procedure

First, the sub-basin and shoreland drainage areas are defined and within each sub-basin, the drainage pattern and type of flow system are identified. Second, the area of each sub-basin is determined. Third, the coefficient of runoff is



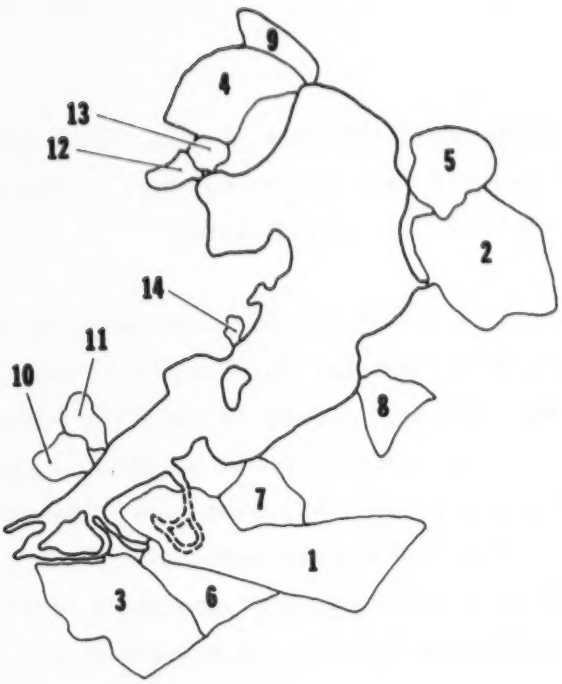


estimated on the basis of soils, slope and land cover. Fourth, with these data, we can compute the discharge (Q) from each sub-basin for any rainstorm.

The fifth step involves assigning coefficients for the water quality (W) and flow efficiency (E) of each sub-basin, and the final step is the actual computation of the influence factors. The sub-basin influence factors for the Silver Lake watershed are given on the map on the following page. The values range from 15. 7 to 0. 3, but most are concentrated between 1 and 4. To help focus attention on the relative importance of the sub-basins in terms of planning and management considerations, a map was constructed

SUB-BASIN INFLUENCE FACTORS
SILVER LAKE

SUB-BASIN RANK
BASED ON INFLUENCE FACTORS



in which each sub-basin was drawn with an area proportional to its influence factor. In other words, the sub-basin with the largest influence factor (15.7) was drawn with an area 52 times larger than the sub-basin with the lowest factor (.3); that is

$$\frac{15.7}{.3} = 52$$

This map is shown on the previous page and it is interesting to visually compare the adjusted sizes of sub-basins with their true sizes.

application to Silver Lake

The I_f values are now checked against the land use of the watershed, and each sub-basin can be given either a planning (p), management (m) or planning-management (p-m) designation. For the fourteen sub-basins in the Silver Lake watershed, seven are designated for management, four for combined planning and management and three for planning. The latter number is significant because it indicates that, considered as a whole, the sub-basin drainage area of Silver Lake is approaching full development. Only one sub-basin, located across from the island on the northeastern shore, is completely undeveloped, while the other two sub-basins with planning designations appear to be in a state of land use flux with development proceeding rapidly in their upper reaches. The upland portions of all the remaining sub-basins are occupied by agriculture which is highly prone to displacement by residential development should the present land use trends in this region continue. While the first order of business is to establish a management program to cope with the existing runoff problems in these sub-basins, it is also necessary to prepare for land use changes by establishing a planning program to guide and regulate the anticipated pressure for residential development of farmland.

section 4

The make-up of a planning program

Formulation of guidelines for shorelands

Weighing the components of the influence factor formula

Planning and management guidelines for sub-basins

Conclusions and recommendations

FORMULATION OF PLANNING AND MANAGEMENT GUIDELINES

The final objective of this report is to highlight some planning and management guidelines that can be used to achieve a lower rate of decline in lake water quality as well as a more pleasing lake environment. Planning and management of lake watersheds are vitally important in order to maintain the basic qualities which make these areas desirable residential and recreational places. Without proper planning and management, haphazarard development is almost certain to reduce the value of the lake environment.

By establishing a sound information base and a well conceived plan, local governments and citizens can provide the best available means for protection of the lake and its sensitive environment. Such a planning program should encourage and facil-

itate desirable uses of the environment as well as regulate and limit undesirable land uses and development practices. A successful planning program entails several major stages or processes:

the elements of a lake watershed planning program

1. Formulation of goals about the kind of lake environment that is desired.
2. Development of a plan that specifies guidelines which can be used to achieve the goals.
3. Implementation of the plan, that is, putting the plan into action.
4. Evaluation of the plan, that is, determining how well impending land use problems are being resolved.

Inland lake watersheds are complex environments and in order to provide a framework for organizing a planning and management program, it is first necessary to subdivide them into shorelands and sub-basins, as illustrated in Section I. A basis is thus established for a two part planning and management program.

shoreland planning guidelines

The part of the planning program dealing with shorelands can be based on the development capacity of frontage property. The plan should be based on sound environmental information that enables us to pinpoint those stretches of shore that are suitable for development (first order sites) as well as those that are unsuitable for development (third order sites). For each order, guidelines can be structured to regulate how such shoreland should be used. In order to achieve implementation, the plan should identify means of enforcing guidelines. For example, third order sites could be zoned against development, or State regulations prohibiting the placement of septic drain fields in saturated soil could be enforced. Finally, the plan should be periodically evaluated. If third order shoreland sites are being developed despite the planning program, then stronger

enforcement of guidelines and even a new plan may be needed.

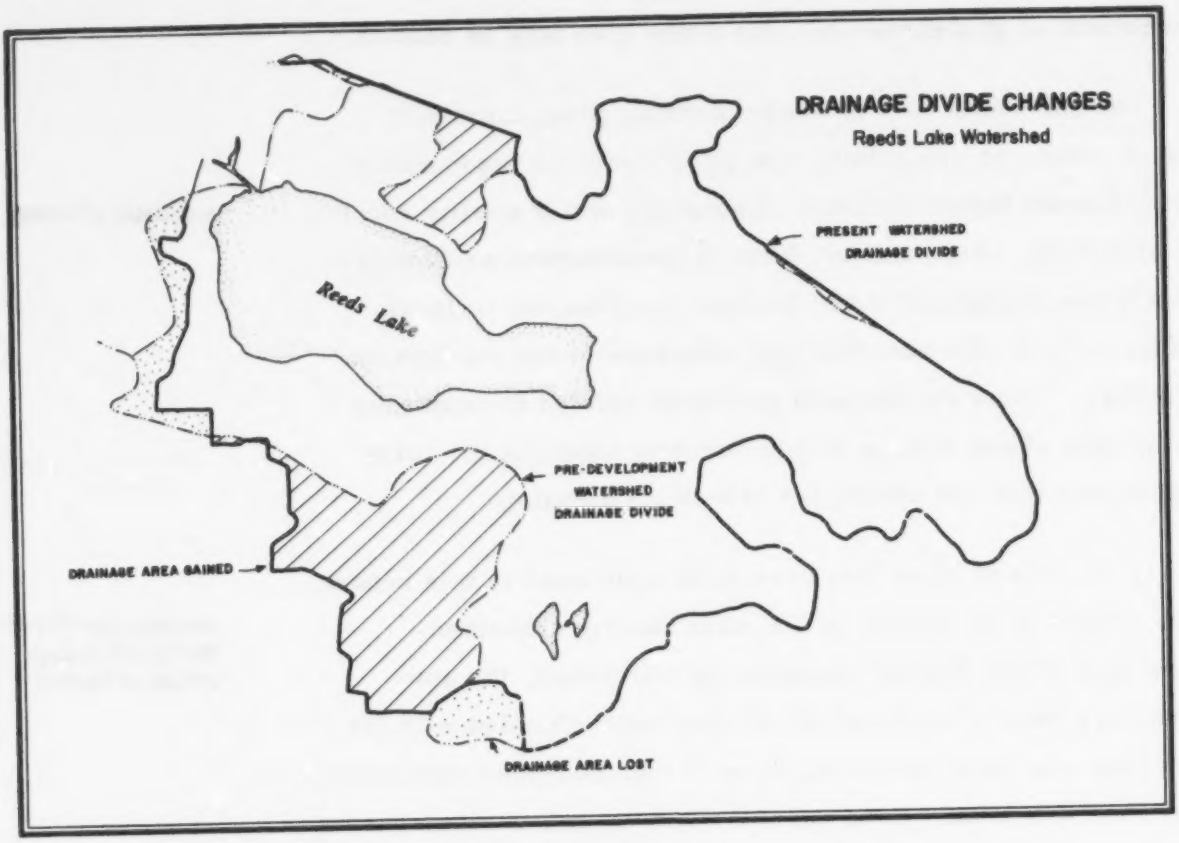
The sub-basin part of a lake planning program should focus on means of minimizing change in the three components of the influence factor formula: discharge, water quality and flow efficiency. Although any form of development will inevitably produce changes in these factors, the planning program should strive to minimize the total influence of the sub-basins on the lake. Some examples of problems related to unplanned development of sub-basins should serve to highlight the sorts of guidelines that are needed for sub-basin planning.

sub-basin planning

Of the inland lakes that have been mentioned in this report, Reeds Lake in Kent County is the most heavily urbanized. Where East Grand Rapids occupies the watershed, the sub-basins have been intensively storm sewered. Coupled with the urban land use, this has produced very high sub-basin influence factors for this area. Upon careful examination, it also appears that in the course of building its storm sewer system, East Grand Rapids has actually pushed the watershed drainage divide south of its natural location. As the map on the following page suggests, this has further increased the influence of the affected sub-basins on Reeds Lake.

development practices that produce high influence factors

In a second example, around the southern end of Silver Lake, extensive channels have been dredged in the lower reaches of several large sub-basins. (See the photograph on the following page). In each case, the channels were cut through wetlands, thereby breeching their important role as filters and regulators of runoff. As a result, the coefficient of flow efficiency of the sub-basins has increased from .3 to .8. In addition, the channels opened the interiors of the sub-basins to the lake and thus encouraged frontage development that otherwise would not have


DRAINAGE DIVIDE CHANGES
Reeds Lake Watershed
PRESENT WATERSHED
DRAINAGE DIVIDE
Reeds Lake
PRE-DEVELOPMENT
WATERSHED
DRAINAGE DIVIDE
DRAINAGE AREA GAINED
DRAINAGE AREA LOST

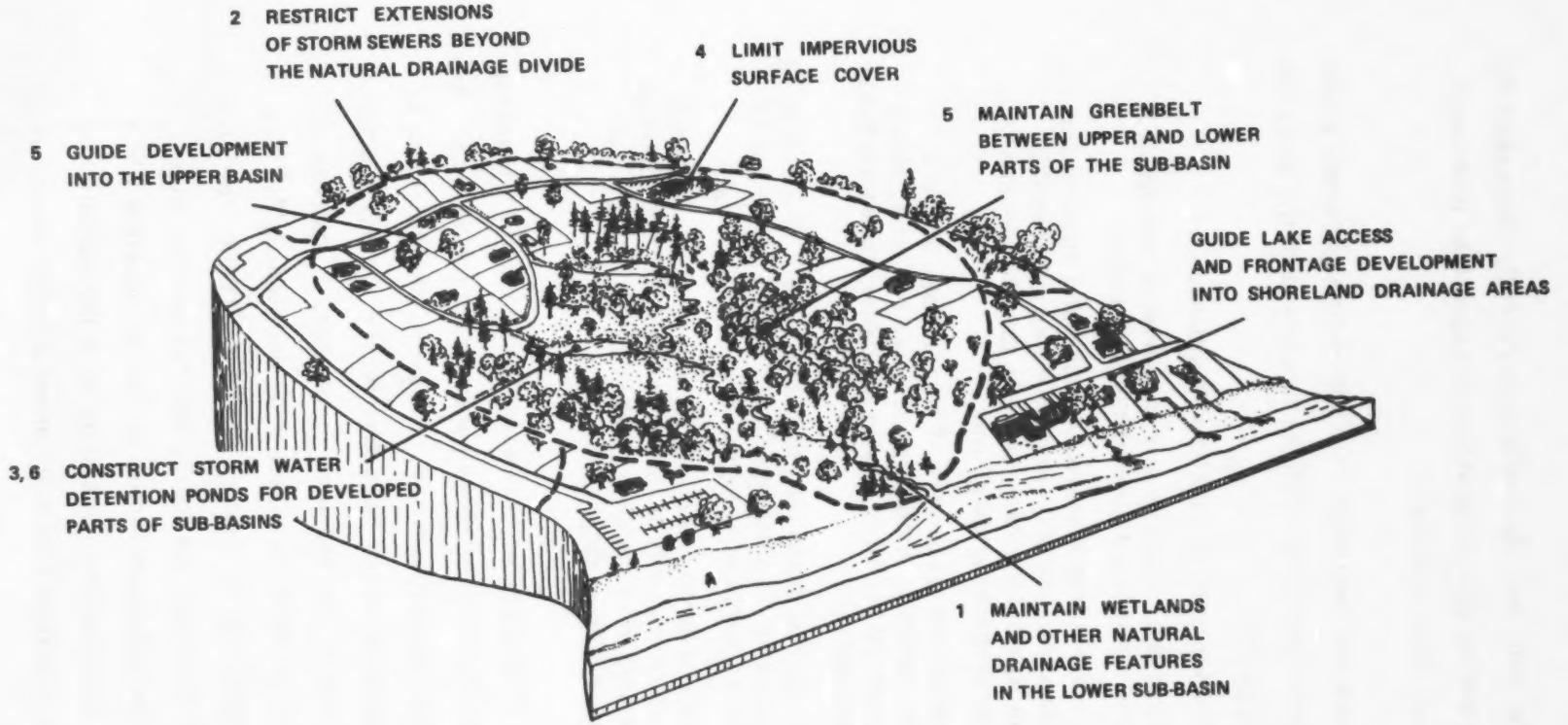
taken place. In sum, the channelization directly increased the flow efficiency and triggered land use changes that increased the coefficient of water quality.

From these two examples, we can define six basic guidelines for sub-basin planning: (These are keyed to the diagram on the following page)

1. Prohibit all channelization of wetlands.
2. Prohibit the extensions of sub-basins beyond the natural drainage divide of the watershed.
3. Minimize storm sewers, ditches and channel improvements; instead, promote local disposal of storm water by means such as those suggested in the accompanying diagrams.
4. Minimize the total area of impervious surface cover; instead, encourage the use of stone, brick and similar pervious materials where hard surfaces are necessary.
5. Guide development into the upper parts of sub-basins and maintain forests and other natural features in the lower parts of sub-basins.
6. Where the upland portions of sub-basins are steep and linked directly to the lake by a stream, provide some means of reducing runoff, e. g., detention ponds or flow dissipators.

sub-basin planning guidelines

It would, of course, be unreasonable to expect a planning program to implement all of these guidelines successfully. Any effort short of full implementation, however, should strive to balance one component of the influence factor against another. That is, if one factor, for instance discharge, is increased, an attempt should be made to offset it by decreasing the flow efficiency or improving the quality of runoff. Thus, the planning objective is to weigh one factor against another in an attempt to hold the influence factor as low as possible while accommodating development consistent with the established goals. But what if extensive development already exists at the


2 RESTRICT EXTENSIONS OF STORM SEWERS BEYOND THE NATURAL DRAINAGE DIVIDE
4 LIMIT IMPERVIOUS SURFACE COVER
5 MAINTAIN GREENBELT BETWEEN UPPER AND LOWER PARTS OF THE SUB-BASIN
5 GUIDE DEVELOPMENT INTO THE UPPER BASIN
GUIDE LAKE ACCESS AND FRONTAGE DEVELOPMENT INTO SHORELAND DRAINAGE AREAS
3, 6 CONSTRUCT STORM WATER DETENTION PONDS FOR DEVELOPED PARTS OF SUB-BASINS
1 MAINTAIN WETLANDS AND OTHER NATURAL DRAINAGE FEATURES IN THE LOWER SUB-BASIN

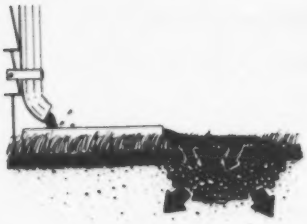
time of plan formulation? Then we must look to a management program to achieve a lowered influence factor.

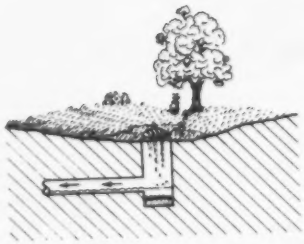
Management programs are designed to augment the operation of a system; in other words, to make it run better. Any measure of how well it runs depends on one's goals. With regard to sub-basin runoff, different factions living in the watershed may have contrasting goals; therefore, there may be disagreement on the nature and success of a management program. For instance, a typical management goal of communities situated in the uppermost part of a large sub-basin is to dispose of storm water in an efficient and economical manner. If the community lacks a strong sense of affiliation with the lake, this can result in conflict with lake property owners who wish to reduce storm water discharge to the lake.

Since it would be irrational to propose removal of impervious surface materials (streets, houses, parking lots, etc.) or major changes in the essential economic activities in a watershed, we are limited to two basic management strategies to improve the influence factor: 1) change certain human activities such that less debris is deposited on runoff surfaces and 2) change the flow efficiency of the drainage network such that less water and cleaner water enters the lake. The first strategy requires a change in public attitudes and activities concerning such practices as lawn fertilizing and leaf burning. This calls for community organization, a set of information on what to do and not to do, as well as a means of spreading the information to residents, businesses and institutions. Several standard programs can be used to achieve this and local planners, extension agents and college and high school personnel can be helpful in selecting and implementing a program. The set of information is available from the Inland Lake Management Unit,

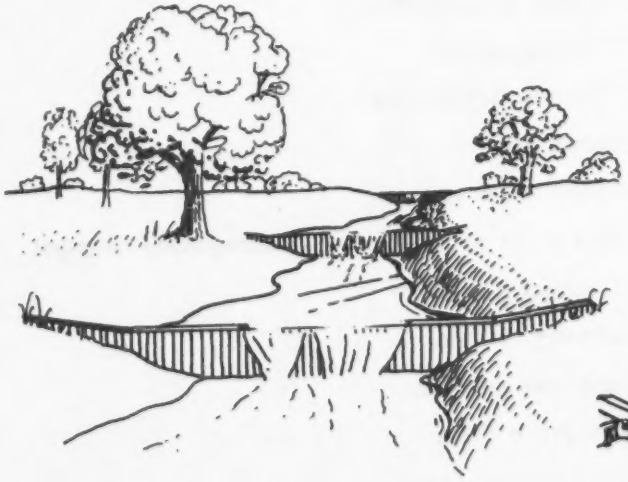
management strategies

Michigan Department of Natural Resources.





The second strategy usually involves the design and construction of various structural devices to reduce flow. Although structures can be placed anywhere in the drainage network, they are usually located in either the upper or lower extremities of the sub-basin. Those built in the upper basin are designed to reduce inflow to storm sewers and ditches. The illustrations below show some of the low cost alternatives, and most of us would agree that they are sufficiently simple that we could build them in our spare time. The structures designed for the lower part of the basin usually involve some sort of holding pond, where discharge and sediment load can be reduced. Although we usually turn to small dams or excavation pits for such purposes, beaver dams appear to be an equally efficient and certainly less expensive, solution in certain sub-basins.



CONCLUSIONS

1. One of the most serious obstacles confronting efforts to apply planning and management concepts to inland lake watersheds is the lack of an analytical methodology that provides data, information and an organizational framework for planning program development. Although methodologies developed for river basins analysis have been helpful, they have never been fully adapted to lake watersheds. A primary thesis of this volume is that inland lake watersheds are comprised of two types of drainage areas: 1) shoreland and 2) sub-basin. These areas are the primary hydrologic units of the lake watershed and they provide a framework for watershed analysis as well as for organization and implementation of planning and management programs.

2. Shorelands are the drainage areas situated on the lakeshore between the mouths of the sub-basins. They are narrow segments of land that lack integrated runoff patterns. The formulation of planning guidelines for shoreland areas can be based on physiographic factors, mainly topography and drainage. Six types of shorelands are commonly found around inland lakes and they can be classed into three orders according to their suitability for development. First order shorelands are well drained sites that allow ample building setback and require little or no alteration for development; second order sites are suitable for limited, planned development; and third order sites are unsuited for any development. Given a definition of shoreland development capacity, a planning program should establish means to restrict development from third

order sites, namely, wetlands, low berms and similar shoreline terrain.

3. Sub-basins are larger and somewhat more complex drainage areas from the standpoint of both analytical and planning considerations. Sub-basins drain the upland part of the watershed where agriculture and community development are widespread. Owing to the considerable distances that often separate the upland part of the sub-basin from the lake, the effect of this drainage area on lake water is not as apparent as that of the shorelands. Priorities for sub-basin planning and management can be based on the influence factor. This is a numerical indicator of the relative effect on lake water of each sub-basin in a watershed and it is based on three factors: discharge of runoff, the quality of runoff and the flow efficiency of the drainage network that carries runoff to the lake. Undeveloped sub-basins with large influence factors should be designated for planning attention, whereas developed sub-basins with large influence factors should be designated for management attention. Partially developed sub-basins should be designated for combined planning and management attention.

4. Guidelines for both planning and management programs should be designed to minimize the influence factor of each sub-basin. This necessitates weighing one component in the influence factor against another. If, for instance, increased development is planned for a sub-basin, then means for reducing the runoff to the lake must also be planned.

APPENDIX
Regional Planning Commissions

REGION 1

Southeast Michigan Council of Governments
8th Floor, Book Building
1249 Washington Boulevard
Detroit, Michigan 48226
(313) 961-4266

Executive Director: Michael M. Glusac
Chairperson: Dr. Conrad L. Mallett

REGION 2

Region 2 Planning Commission
Room 220, 312 South Jackson Street
Jackson, Michigan 49201
(517) 787-3800, ext. 256

Executive Director: Charles R. Mancherian
Chairperson: Oliver Sweitzer

REGION 3

Southcentral Michigan Planning Council
Connors Hall, Nazareth College
Nazareth, Michigan 49074
(616) 343-1678

Executive Director: Robert L. Hegel
Chairperson: Bess H. Jordan

REGION 4

Southwestern Michigan Regional Planning Commission
2907 Division Street
St. Joseph, Michigan 49085
(616) 983-1529

REGION 5

GLS Region V Planning & Development Commission
100 Phoenix Building
801 South Saginaw Street
Flint, Michigan 48502
(313) 766-8594

Executive Director: Thomas Haga
Chairperson: Gerald H. Cummings

REGION 6

Tri-County Regional Planning Commission
2722 East Michigan Avenue, P.O. Box 2066
Lansing, Michigan 48912
(517) 487-9424

Executive Director: Herbert D. Maier
Chairperson: Almond B. Cressman

REGION 7

East Central Michigan Planning & Development Regional Commission
1003 Woodside
Essexville, Michigan 48732
(517) 893-5561

Executive Director: David W. Gay
Chairperson: Mrs. Connie Miskov

REGION 8

West Michigan Regional Planning Commission
1204 People's Building
60 Monroe at Ionia
Grand Rapids, Michigan 49502

Executive Director: Robert L. Stockman

REGION 9

Northeast Michigan Regional Planning & Development Commission
Old Hospital Building
131 Shipp Street, P.O. Box 457
Gaylord, Michigan 49735
(517) 732-3551

Executive Director: Rodney Parker
Chairperson: Keith S. Titus

REGION 10

Northwest Michigan Regional Planning & Development Commission
2334 Aero Park Court
Traverse City, Michigan 49684
(616) 946-5922

Executive Director: Bill G. Rowden
Chairperson: Dayton Willard

REGION 11

Eastern Upper Peninsula Regional Planning and Development Commission
Lake Superior State College
Sault Ste. Marie, Michigan 49783
(906) 635-1581

Executive Director: John W. Campbell
Chairperson: Harold L. Dettman

RECOMMENDATIONS FOR FURTHER STUDY

1. The method proposed for generating and recording information should be tested with a group of property owners such as a lake association, and the information should be evaluated for its utility in watershed analysis, planning and management.

2. The watershed analysis and planning and management methods recommended in this report should be tested in several different types of lake areas, e. g., fully developed, undergoing development and undeveloped. This effort should not only be designed to test and refine methods, but also to identify the appropriate combination of local, county and State agencies necessary to achieve satisfactory action.

3. Based on the test results, a handbook should be prepared to help guide citizens, local officials and planners in organizing and putting into action the information, analytical and planning and management parts of the methodology presented in this report.

4. The method for determining the influence factor for subbasins is suitable for establishing planning and management priorities; however, in its present state of development, it is of limited utility for analytical purposes. Nevertheless, the method does point the direction for some important research if hydrologic and water quality data are to make meaningful contributions to planning and management programs. Among other things, such research should focus on formulating a set of standard water quality coefficients keyed to non-point runoff from differ-

ent land uses. This would not only facilitate a more analytical approach to the planning and management of small drainage basins, for instance, affording a stronger basis for predicting change, but also reduce the need (and hence, the costs) of extensive field surveys for sampling non-point runoff.

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